THE IMPACT OF PREVENTIVE MAINTENANCE ON BUILDING MAINTENANCE OUTCOMES: A CASE STUDY OF GOVERNMENT BUILDING IN PARCEL C AT PUTRAJAYA

MUHAMMAD HAZIM AIMAN BIN HAZMAN

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Muhammad Hazim Aiman Bin Hazman

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MUHAMMAD HAZIM AIMAN BIN HAZMAN

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Cop Rasmi:

TS. AHMAD NIZAM BIN JAMALUDIN
Jurutera Pengajar Kanan
Fakulti Teknologi Dan Kejuruteraan Mekanikal
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Signature :

Supervisor Name : *Ts AHMAD NIZAM BIN JAMALUDIN*

Date : 9/1/2024

Signature :

Zahirul Amir bin Zainordi
Pengurus Fasiliti Kompleks C
WP Putrajaya
HBS ENGINEERING SDN. BHD.

Co-Supervisor Name : *MR ZAHIRUL AMIR BIN ZAINORDI*

Date : 9/1/2024

DEDICATION

To my beloved parent, Hazman Bin Che Sidik and Rozaiha Binti Mahmmud, for your patience and everything with love. To my brother Muhammad Amirul Asyraf Bin Hazman and my sister Nur Atiqah Nabila Binti Hazman for their continuous support and encouragement while I have been away from home.

ABSTRACT

The proposed research aims to investigate the impact of preventive maintenance on building maintenance outcomes in the government sector in Complex C at Putrajaya. The study will use a case study approach, selecting several government buildings for in-depth analysis. The selected buildings will represent various types and sizes and varying degrees of maintenance history and conditions. The research had three objectives. First, determine the effectiveness of preventive maintenance in improving building maintenance outcomes. Second, to plan preventive, corrective, and scheduled maintenance to be more efficient. Third, to improve the quality of preventive maintenance. The study will collect data on building maintenance history, including the type and frequency of repairs, and data on preventive maintenance activities such as inspections, cleaning, and regular maintenance. The findings from the case studies will be analyzed to determine the impact of preventive maintenance on building maintenance outcomes and identify best practices for implementing preventive maintenance in government buildings. The findings from the study will be valuable for building maintenance practitioners, policymakers, and decision-makers in the government sector, as evidence-based recommendations to improve building maintenance outcomes through the implementation of preventive maintenance will be given.

ABSTRAK

Penyelidikan yang dicadangkan bertujuan untuk menyiasat kesan penyelenggaraan pencegahan terhadap hasil penyelenggaraan bangunan di sektor pemerintah bangunan di tapak C di Putrajaya. Kajian ini akan menggunakan pendekatan kajian kes, memilih beberapa bangunan pemerintah untuk analisis mendalam. Bangunan yang dipilih akan mewakili pelbagai jenis dan ukuran, serta pelbagai tahap sejarah dan keadaan penyelenggaraan. Penyelidikan ini mempunyai tiga objektif. Pertama, menentu keberkesanan penyelenggaraan pencegahan dalam meningkatkan hasil penyelenggaraan bangunan. Kedua, merancang penyelenggaraan pencegahan, pembetulan dan jadual agar lebih efisien. Ketiga, untuk meningkatkan kualiti penyelenggaraan pencegahan. Kajian ini akan mengumpulkan data mengenai sejarah penyelenggaraan bangunan, termasuk jenis dan frekuensi pembaikan, serta data mengenai aktiviti penyelenggaraan pencegahan seperti pemeriksaan, pembersihan, dan penyelenggaraan berkala. Penemuan dari kajian kes akan dianalisis untuk menentukan kesan penyelenggaraan pencegahan terhadap hasil penyelenggaraan bangunan dan mengenal pasti amalan terbaik untuk melaksanakan penyelenggaraan pencegahan di bangunan kerajaan. Penemuan dari kajian ini akan sangat berharga bagi pengamal penyelenggaraan bangunan, pembuat dasar dan pembuat keputusan di sektor pemerintah, kerana cadangan berdasarkan bukti untuk meningkatkan hasil penyelenggaraan bangunan melalui pelaksanaan penyelenggaraaan pencegahan akan diberikan.

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In the Name of Allah, the Most Gracious, the Most Merciful

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This thesis is dedicated to my family, especially my mother, Rozaiha Mahmmud, and my father, Mr. Hazman Che Sidik, for having the foresight and perseverance to educate me. I dedicate this win to the two of you. Finally, I want to thank everyone directly or indirectly involved in this research. The person that provided me with recommendations, advice, and assistance for my project.

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LIST OF SYMBOLS AND ABBREVIATIONS

PM	Preventive Maintenance
CM	Corrective Maintenance
CMMS	Computerized Maintenance Management System
CBM	Condition Based Maintenance
PdM	Predictive Maintenance
FBM	Failure-based Maintenance
BM	Breakdown Maintenance
PD	Planned Downtime
UD	Unplanned Downtime
OEE	Overall Equipment Effectiveness
AHU	Air Handling Unit
RCA	Root Cause Analysis
MTTF	Mean Time To Failure
MDT	Mean Down Time
DX	Direct-Expansion

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CHAPTER 1

INTRODUCTION

1.1 Background

Maintenance is a term that can mean a variety of things to various people. Numerous authors have put their spin on defining and redefining the term(Lateef et al., n.d.). On the other hand, it appears from the multiple definitions that maintenance concerns the care of buildings. Maintenance management started in 1971 for buildings in Malaysia(Zulakhmar Zakiyudin et al., n.d.). Despite this, in this article, maintenance is defined as the required processes and services undertaken to preserve, protect, enhance, and care for the buildings' fabrics and services after completion, following the prevalent standards to enable the building and services to serve their intended functions throughout their entire life span without significantly upsetting their fundamental features and uses. A building is an asset, and the value of that asset fluctuates depending on the quality (and quantity) of the maintenance invested in it(Lateef et al., n.d.).

A case study is used throughout this article to demonstrate how a government building in Putrajaya's Complex C can effectively manage its maintenance services and the impact of preventive maintenance. According to the findings of this study, the term "system" refers to either the decision-making framework or the rules for managing parcel C(Lateef et al., n.d.). Therefore, a framework for making decisions on the upkeep of buildings in Putrajaya's Complex C is meant by the term "Complex C building maintenance management system." Personnel, procedures (as well as materials, tools, equipment, and facilities), activities, tasks, and rules make up the system in this context. Chapter 2 of this study is devoted to a literature review on the various building maintenance practices practiced in government buildings in Putrajaya's Complex C. Chapter 3 of the report breaks down the methodology and research design. In the fourth portion of the information, a case study is presented, in which the assessment, evaluation, and discussion of the maintenance management of a government building in Putrajaya's Complex C are conducted. This investigation sheds light on various processes utilized within the building maintenance system at the government buildings in Putrajaya's Complex C. Chapter 4 will offer a synopsis of the findings derived from the case study. Chapter 5 contains our concluding thoughts and observations.

1.2 Problem Statement

The problem that occurred in building Complex C at Putrajaya is the high number of maintenance work orders within an organization, which is caused by multiple factors, including a lack of a proper preventive maintenance plan and a propensity to ignore deadlines for corrective and preventive maintenance tasks.

First, the absence of a well-structured plan for preventive maintenance is a significant factor in the rising costs. Without a proactive approach to identifying and resolving future problems before they escalate, equipment malfunctions and breakdowns increase. As a result, the organization must devote substantial resources to emergency repairs and replacements, which are frequently more costly and time-consuming.

Second, the problem is exacerbated by missed corrective maintenance deadlines. When maintenance tasks are not completed within the specified timeframes, minor issues can escalate into significant ones, resulting in extensive damage and costly repairs. In addition, ignoring preventive maintenance deadlines increases the likelihood of unexpected failures, disrupts operations, and extends downtime, which significantly negatively impacts the organization's productivity and overall efficiency.

The absence of an adequate plan for preventive maintenance and the tendency to miss deadlines for corrective and preventive tasks contribute to the overall high number of work order maintenance. To overcome these obstacles, it is necessary to implement a preventive maintenance strategy that prioritizes routine inspections, timely restorations, and adherence to maintenance schedules. Consequently, the organization can reduce the number of work orders, optimize equipment performance, and improve operational effectiveness.

1.3 Research Objective

The main objectives of this research are:

a) To determine the effectiveness of preventive maintenance in improving building maintenance outcomes.

b) To plan preventive, corrective, and scheduled maintenance to be more efficient.

c) To improve the quality of preventive maintenance.

1.4 Scope of Research

Many scopes of work will help elaborate the study's objectives and delimit the project. First, the project will focus on improving the efficiency of preventive maintenance actions and corrective maintenance buildings in Complex C Putrajaya. Therefore, the maintenance schedule should be enhanced to achieve the objectives. In addition, the project also focuses on reducing the number of maintenance work orders by using root cause analysis methods to identify the root cause of the problem for each component in AHU.

1.5 Significance of Study

The significance of this study will determine the effectiveness of preventive maintenance in improving the outcome of building maintenance by establishing a planning and scheduling process. By using the root cause analysis method, this research can help building maintenance to reduce corrective maintenance. Thus, the quality of preventive maintenance can be improved.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

By conducting an in-depth analysis of the vast body of published work contributed by professionals working in the same industry, this chapter investigates the history of the research, explains the current state of the investigation, and provides knowledge of the subject at hand. It has been ensured that all relevant information and sources, with the primary focus being placed on published papers, journals, books, and other related bodies of knowledge, have been compiled. This chapter summarizes all prior studies on maintenance, planning and scheduling, maintenance management, asset management, and computerized maintenance management systems (CMMS). Researching all relevant issues before beginning a case study is critical to obtaining more valid data.

2.2 Maintenance

According to the official definition, maintenance is a combination of all technical, administrative, and management actions taken throughout a product's lifecycle to keep the item in good working order or restore it to that condition(Soesatijono & Darsin, 2021). The primary duty of maintenance is to render a service that helps a company accomplish its goals(Martins et al., 2020). To avoid any failure that could cause a halt in production, maintaining a system typically entails maintenance procedures like repairing, replacing, overhauling, inspecting, servicing, adjusting, testing, measuring, and fault detection(Basri et al., 2017). In today's business world, preventive maintenance is widely recognized as an indispensable element of day-to-day operations. The success of an organization and its ability to continue existing in its current form is directly correlated to the maintenance system's level of usefulness and productivity.

There are two different types of production maintenance, scheduled and unplanned. Breakdown maintenance is typically unplanned, whereas planned maintenance is divided into preventive and corrective maintenance(Mansor et al., 2012). Fixed and predictive maintenance are two subcategories divided from preventive maintenance. The different types of maintenance are outlined in Figure 1. If scheduled maintenance is carried out well, it will result in a reduction in the amount of unplanned maintenance that is required.

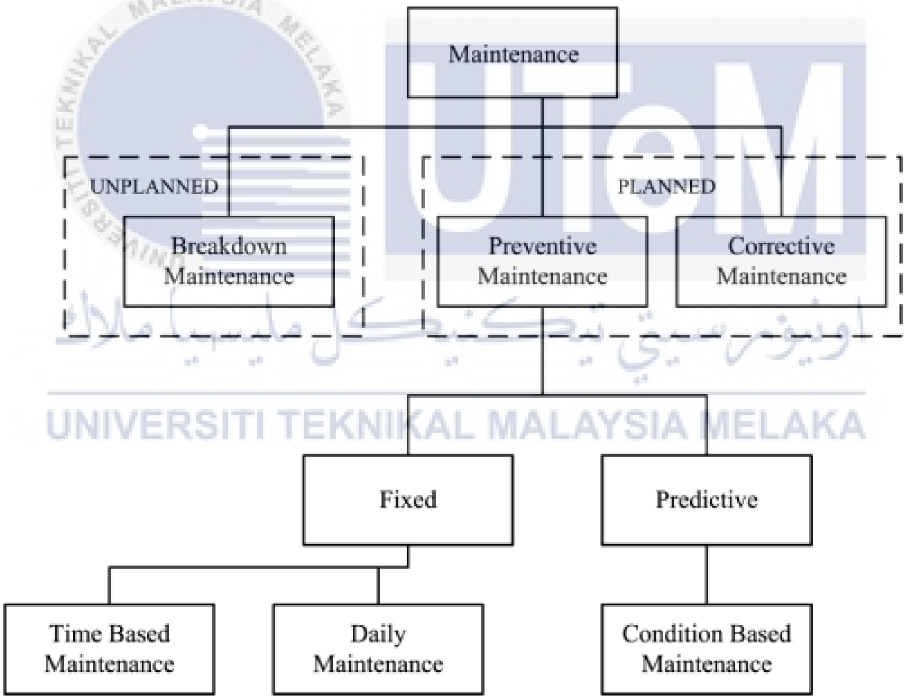

Figure 2. 1 Types of Maintenance(Mansor et al., 2012)

2.2.1 Preventive Maintenance

"Maintenance that is carried out at predetermined intervals or according to prescribed criteria and is intended to reduce the probability of failure or the degradation of the functioning of an item" is one definition of preventive maintenance (PM). Another definition of PM is "maintenance that is carried out at predetermined intervals or according to prescribed criteria(Rastegari, 2015)." In other words, PM is daily maintenance (cleaning, lubricating, oiling, tightening, and inspection) targeting to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection, or equipment condition diagnosis to measure deterioration. PM aims to keep the equipment in good working condition for as long as possible(Soesatijono & Darsin, 2021). PM refers to maintenance procedures before a piece of machinery is broken. Condition Based Maintenance(CBM), or planned or periodic maintenance, is one form of PM(Rastegari, 2015). PM and predictive maintenance (PdM) are proactive maintenance techniques with similar goals, but PM is carried out when a machine is stopped, and PdM is carried out when a device is still in use(Basri et al., 2017).

PM is realized from different views, referred to as the managerial and operational perspectives. The managerial perspective is the support for decision-making that makes analyzing facts easier. This is also known as the managerial perspective. Inputs from the managerial perspective include the determination of the objectives of PM, the planning to undertake maintenance actions, the procedures involved in solving any PM-related problem, and the performance of systems(Basri et al., 2017). Because it makes judgments predicted on history and analysis rather than the activities to be taken by the PM, the managerial perspective is also known as an outside process. In the meantime, the term "operational perspective" refers to the process of carrying out maintenance tasks to keep a system in a state where it can continue to carry out the functions for which it was originally designed. This perspective is an internal process comprised of technical features utilized in the execution of PM depending on inputs from the outside process(Basri et al., 2017).

2.2.2 Corrective Maintenance

Corrective maintenance (CM) is defined as maintenance performed on an item after a fault has been identified and is designed to bring the item back to a state where it can perform the needed function(Mydin, 2015). There are occasions when it is used interchangeably with the terms failure-based maintenance (FBM) and breakdown maintenance (BM)(Rastegari, 2015). CM, also known as run-to-failure maintenance or reactive maintenance, is a technique that is used to restore (repair or replace) equipment to its needed function after it has failed(Rosmaini Bin Ahmad, 2007). The strategy is used to restore equipment to its required function after it has failed. It enhances both the equipment and the components of that equipment, making it possible for PM to be carried out more reliably(Soesatijono & Darsin, 2021). It is necessary to redesign equipment with design flaws to increase its dependability or improve its maintainability.

2.2.3 Predictive Maintenance

Using predictive maintenance, an organization can predict impending failures before they become catastrophic. It is the method that assists the user in planning the work that needs to be done on the equipment to prevent unexpected failure. This technique is essential to our study question. Decisions are made in predictive maintenance based on the data gathered from condition monitoring. The steps involved in condition monitoring are data collecting, data processing, and maintenance decision-making. The use of condition monitoring can avoid equipment failure. It also helps to prevent breakdowns that were not planned for and to maximize the use of maintenance resources by arranging maintenance or shutdowns based on the collected data. Any failure mode can benefit from predictive maintenance as long as it can be demonstrated to be technically viable and worthwhile to implement. The condition of the equipment or the component is evaluated regularly to anticipate when the part may become defective. Only at that point can the scheduling of the replacement or renovation begin(Lawrence Kau, 2016a).

2.2.4 Condition Based Maintenance

Condition Based Maintenance (CBM) is carried out following a forecast that is formed from repeated analysis of available features and evaluation of the significant parameters of the deterioration of the item is what is meant by the term “predictive maintenance”(Soesatijono & Darsin, 2021). In general, CBM can be viewed as a way to reduce the uncertainty associated with the performance of maintenance operations(Rastegari, 2015). This is a method in which an important part of service life is anticipated based on inspection or diagnosis. The method aims to use the parts until they have reached their maximum service life(Soesatijono & Darsin, 2021). CBM is what we refer to as predictive maintenance, which is different from preventive maintenance. It controls trend values by measuring and analyzing deterioration data and employs a monitoring surveillance system. In addition, it measures and analyses data about deterioration.

CBM is carried out following the needs suggested by the state of the equipment(Rastegari, 2015). As a result, CBM enables us to recognize and address potential issues well before any product harm might occur. Any harm to a product might have significant repercussions within the framework of an industrial system. CBM is a very tempting method for a sector that operates high-valued assets because of its benefits. In CBM, the lifetime (age) of the equipment is tracked by monitoring its working condition(Rastegari, 2015). This condition is evaluated based on several monitoring factors: vibration, temperature, lubricating oil, pollutants, and noise levels. CBM is essential for ensuring equipment's health management, reducing its life cycle cost, and preventing catastrophic failure(Rastegari, 2015). The CBM is the maintenance plan that recommends actions to be taken for maintenance based on the information obtained via the condition monitoring process.

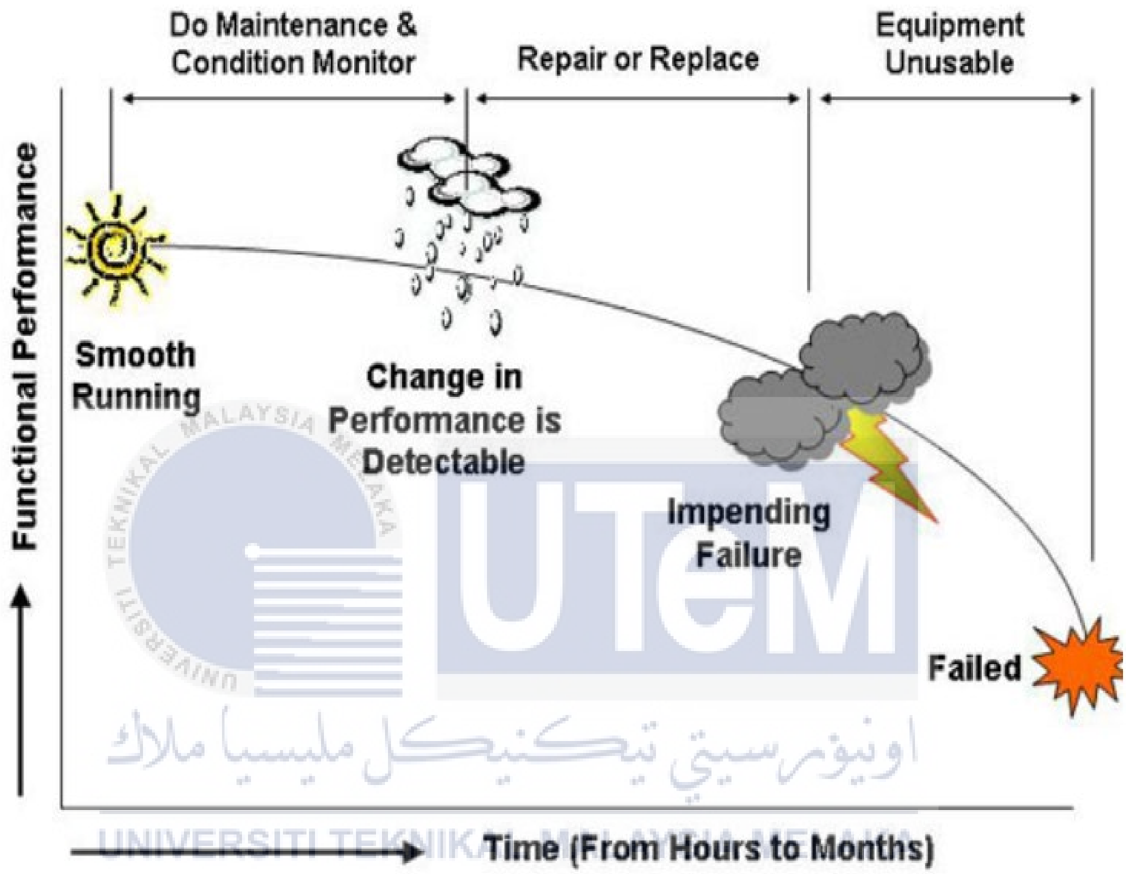

Figure 2. 2 Typical degradation process took place by any equipment (Mydin, 2015)

2.2.5 Pros and Cons PM, CM and CBM

Table 2. 1 Pros and Cons of PM, CM, and CBM(*Publisher's Version / Version de l'éditeur*, n.d.)

PREVENTIVE MAINTENANCE	CORRECTIVE MAINTENANCE	CONDITION BASE MAINTENANCE
Fix it routinely before it breaks	Run to failure	Don't fix it if it is not going to break
+ Maintenance is controlled + Stored parts and costs can be controlled +Unexpected failures should be reduced	+ Facility is not over maintained + No initial investment +Low costs	+Unexpected failures are reduced + Parts and maintenance are done when it's needed +Facility life is extended
- Facilities are maintained when there is no fault - Unscheduled breakdowns cannot be avoided	- High risk of secondary failure - Unscheduled and possibly long downtime	-High operation cost -Additional skills required

2.3 Downtime

Downtime refers to any unplanned interruption of production for some time. The following types of downtime fall under this category:

Planned downtime (PD) is the time that should have been spent operating a plant. Instead, it is being taken up by events scheduled in advance and during which there is no intention of keeping the facility operational. These events include holidays, scheduled maintenance, and breaks. Plant operating time, also written as PO(t), refers to the total time a plant is available for use in an operational capacity. Planned production time, abbreviated as PP (t), is the standard against which unscheduled downtime incidents are evaluated. Unplanned Downtime (UD) measures the loss of planned production time due to unplanned events that cause downtime and negatively affect OEE. Unplanned events such as operator error, mechanical problems, and lack of oversight are among the widest reasons leading to unplanned downtime. When operations are halted, each of these occurrences occurs. When the length of time each event takes into account is combined, the overall amount of unplanned downtime may be calculated(Hidayatullah et al., 2022).

2.4 Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness, abbreviated as OEE, is a metric extensively utilized for evaluating the effectiveness of individual pieces of equipment and the effectiveness of integrated equipment systems. The overall equipment effectiveness (OEE) indicator is becoming an increasingly popular choice for production-related quality assurance and productivity enhancement initiatives. OEE benchmarking allows companies to track their progress and improve their manufacturing performance, which are important goals for any organization. Consequently, OEE has developed into a crucial driver for improvement activities that are carried out once the deficiencies in the equipment have been identified. OEE is an acronym for overall equipment effectiveness, and its primary function is to assist management in reclaiming unused production capacity, minimizing production losses, and determining whether or not additional capital investments are required. It is important to note that higher OEE values translate into better cost savings due to the increased efficacy of the equipment down, and the time for each event is added, so the total amount of unplanned downtime can be computed. This is one of the most important benefits of higher OEE values(Prakash et al., 2019).

2.5 Preventive Maintenance Scheduling

A PM schedule is a strategy for organizing a company's resources to guarantee that maintenance chores are executed according to time or usage triggers. PM schedules are beneficial. The primary objective of PM is to preserve the assets in question in the best possible operational state. The practice of carrying out maintenance tasks following predetermined timetables as a means of minimizing unanticipated breakdowns in the future is known as preventive maintenance. When developing a program for PM, one should consider who will carry out the required work and at what intervals.

One of the primary goals of implementing PM in this organization is to create a detailed PM schedule while still producing the desired results. As part of the plan to accomplish this objective, the PM schedule will be divided into clusters, each with a designated technician(Ab-Samat et al., 2012). The utmost emphasis is given to ensuring that critical machines have all their spare parts in hand and are ready to go well before any potential breakdowns, along with any other remedial measures that may be required(Ab-Samat et al., 2012). Aside from that, the timetable needs to provide a clear timeline, particularly with periodic maintenance (where certain machine parts need to be maintained or changed after a given amount of time)(Ab-Samat et al., 2012).

In addition to that, the PM schedule needs to be organized by a technician. Every one of them will concentrate on the machines corresponding to the ideas, strategies, and tactics they have been given(Ab-Samat et al., 2012). Therefore, the effectiveness of maintenance work can be improved by utilizing all technicians to their maximum potential. To successfully implement PM, the essential quality is ensuring that this timetable will make things easier for technicians.

2.5.1 Effective Preventive Maintenance Scheduled

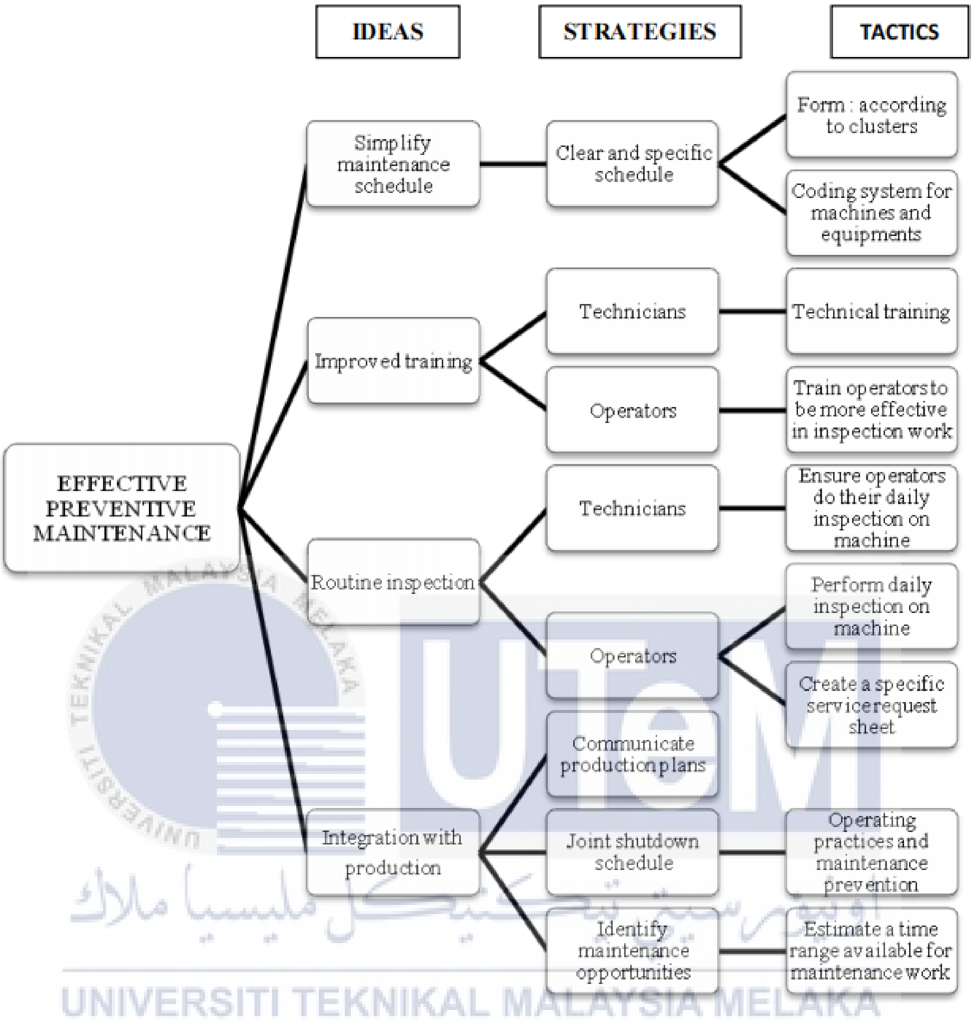

Figure 2. 3 Analysis of effective PM using tree diagram (Ab-Samat et al., 2012)

Figure 2.3 shows how the submitted concepts for effective PM implementations were evaluated for their strategies and tactics. The primary concepts generated for this PM are to have a straightforward maintenance plan, conduct training for technicians and operators on how to keep machines in excellent condition, perform routine inspections, and integrate the process with production (Ab-Samat et al., 2012).

The maintenance staff must periodically undertake PM alongside productions to fully integrate with productions. Discuss your plans to stop production for a period with production so that you can perform PM and create a mutual shutdown schedule(Ab-Samat et al., 2012). When done, the machine may be maintained with fewer or no breakdowns. It is not just dependent on operators to know how to fix their machines, though operators will also know how to repair their machines(Ab-Samat et al., 2012).

2.5.2 Ineffective Preventive Maintenance Scheduled

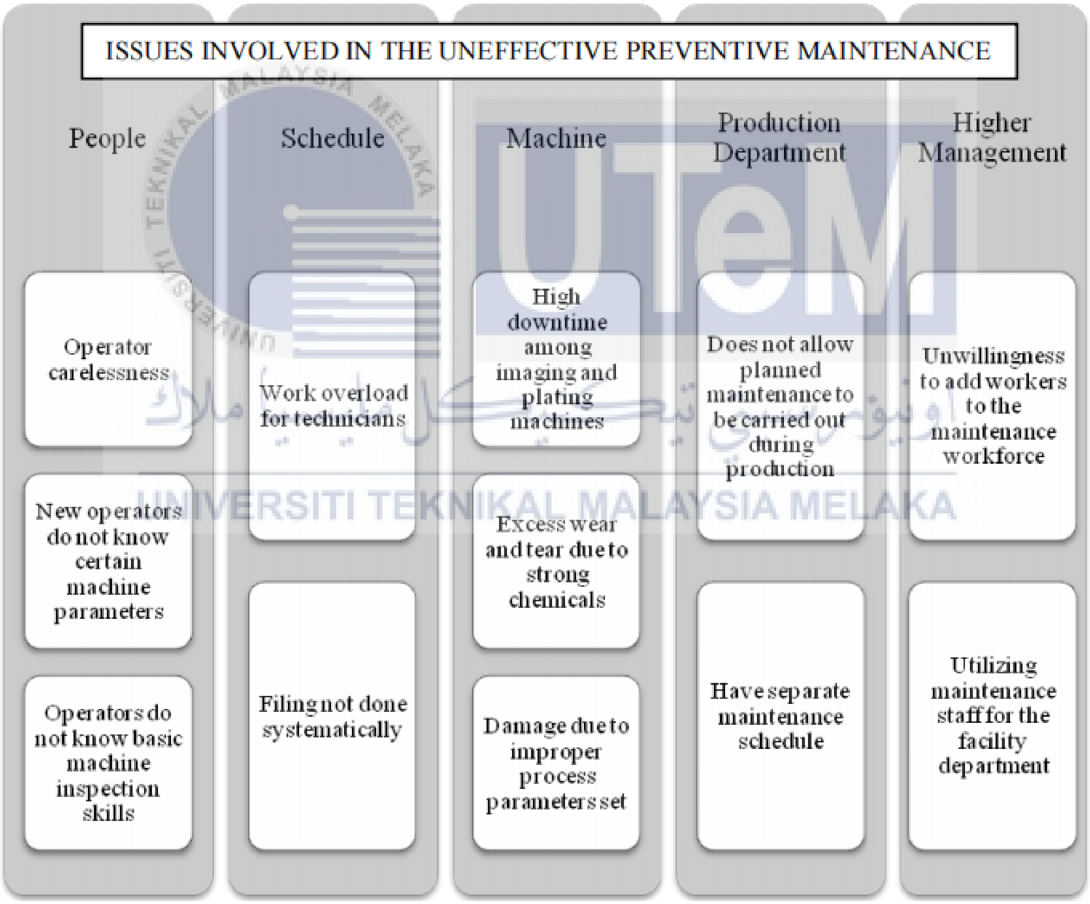

Figure 2. 4 Causes of Ineffective Maintenance (Ab-Samat et al., 2012)

2.6 Preventive Maintenance Planning

In the context of maintenance, planning refers to the activities carried out with the assistance of all maintenance resources, such as the determination and preparation of material requirements, labor requirements, time assignments, and technical references related to equipment, in advance of the performance of a task. In other words, the lack of good planning will result in inconsistent and unreliable procedures, which may lead to pauses in production(Basri et al., 2017). Consequently, effective planning is the preparation for carrying out critical maintenance chores in a prioritized manner by referencing the relevant resources, information, and timetable(Basri et al., 2017).

Maintenance planning involves a long-term strategy for completing maintenance tasks within a set period. PM is one of the many maintenance policies, and it is relevant to that maintenance planning(Basri et al., 2017). This ensures that a system continues to fulfill its intended function. The purpose of PM planning is to assist decision-making in situations of actions that need to be taken and the system's performance that needs to be monitored and improved. The scope of PM planning encompasses all the parts of a PM that need to be integrated with planning to do so(Basri et al., 2017). Before the execution of PM on a system, it is necessary to evaluate objectives, planning, and techniques to fulfill the requirements of PM planning, which is a component of the managerial perspective. To guarantee that the PM activities are carried out in a reliable and standardized manner, the process of establishing PM planning must incorporate both PM policy and planning at some point (Basri et al., 2017). This is something that must be done from a managerial point of view. Having adequate objectives, planning, and methods is essential to provide better knowledge and proper guidelines to develop and refine PM planning. This is why having proper objectives, planning, and methods is so important(Basri et al., 2017).

The research that has been done on PM planning has focused on several different issues that are connected to the maintenance environment(Basri et al., 2017). This study narrows the focus of PM planning and places it on the concept below PM planning. This concept encompasses the goals behind PM's performance, the state of the systems involved, and the methods implemented to tackle maintenance difficulties(Basri et al., 2017).

2.6.1 Preventive Maintenance Concept

In general, the concept of PM planning is stated in a nutshell as the overarching principle that addresses PM aspects in a straightforward and organized way(Basri et al., 2017). Analyzing the qualities of the conceptual description and the requirements and application domains is the starting point for the procedure used to determine a PM planning concept. Therefore, in this study, the literature on the PM planning concept that is reviewed and discussed consists of three aspects:

i. The objective(s) or the purpose of performing PM planning

ii. Descriptions of the system's state in terms of its importance and its functions

iii. Methods that are divided into several classifications to assist in determining the best solutions for the issues that have been highlighted.

These aspects are essential since they serve as a guide for evaluating the literature and its content, which is why they are vital. In the following sections, we will delve further into each component of PM planning and describe it in greater detail(Basri et al., 2017).

2.7 Maintenance Management

The maintenance management is tied to the state of the building services to ensure that they satisfy the criteria required to be carried out as intended. According to several studies, maintenance management encompasses a wide range of activities, each of which can be viewed as an effective application of available resources, enabling techniques and establishments to work following what customers anticipate(Sanusi, n.d.). Maintenance management aims to find the optimal mix of building maintenance methods by selecting the most appropriate maintenance approach for each building component. To guarantee high-quality services, the maintenance management method should be assessed consistently(Sanusi, n.d.).

2.7.1 Maintenance Management Process

As shown in Figure 2.5: it is essential to remember that maintenance management needs to be aligned with business operations on all three levels: strategic, tactical, and operational(Rastegari, 2015).

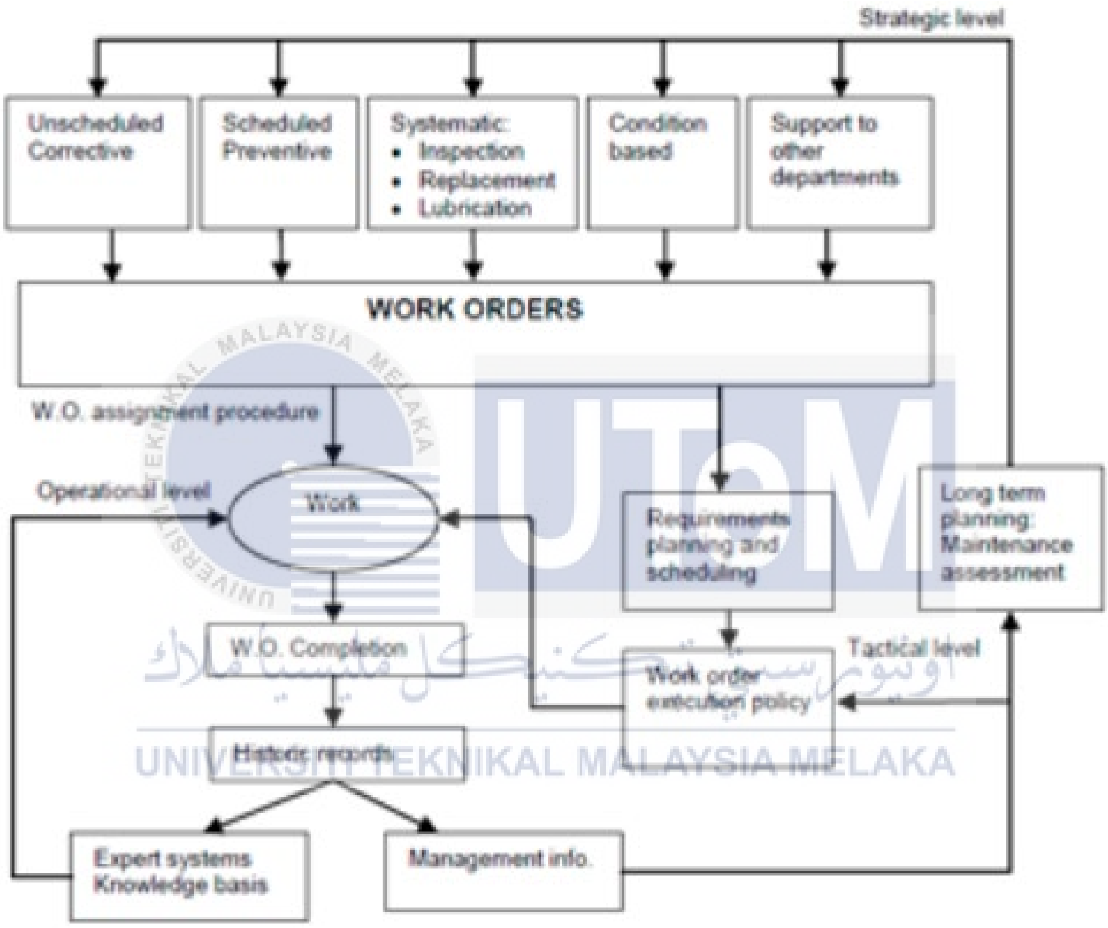

Figure 2. 5 Maintenance process, course of action, and feedback operating at the three levels of business activities(Rastegari, 2015).

2.7.2 Computerized Maintenance Management System (CMMS)

A computerized maintenance management system, also known as a computerized maintenance management information system (CMMIS), is a software package that maintains a computer database of information on an organization's or company's maintenance operations process. Other names for this software package include the computerized maintenance management information system (CMMIS)(Alshokry et al., 2021). This information is meant to help maintenance workers. Developers do their jobs more successfully, and it is also intended to help management make informed decisions when making changes or performing maintenance on the system.

A CMMS provides its users with a variety of maintenance-related features and processes. It is not confined to software systems but spreads to facilities, manufacturing, utilities, fleet, hospitals, and more, where any systems, equipment, and assets may be subject to repair and need maintenance or change(Labib, 2004). Some of the classes and functions of CMMS are illustrated in the figure. Instead of relying on manual techniques to keep track of and organize information concerning maintenance or change operations, an increasing number of businesses and organizations are switching to computerized maintenance management systems (CMMS) due to advancements in technology and an increase in the complexity of their tasks(Alshokry et al., 2021).

Any organization or corporation that needs to maintain equipment, assets, or systems, such as a software system, is a candidate for using CMMS software packages. These programs are available for purchase online. Certain CMMS products are tailored to meet the needs of specific industries, such as those involved in the repair of vehicles, health care, or industries. Other CMMS products strive to be more generic in their functionality.

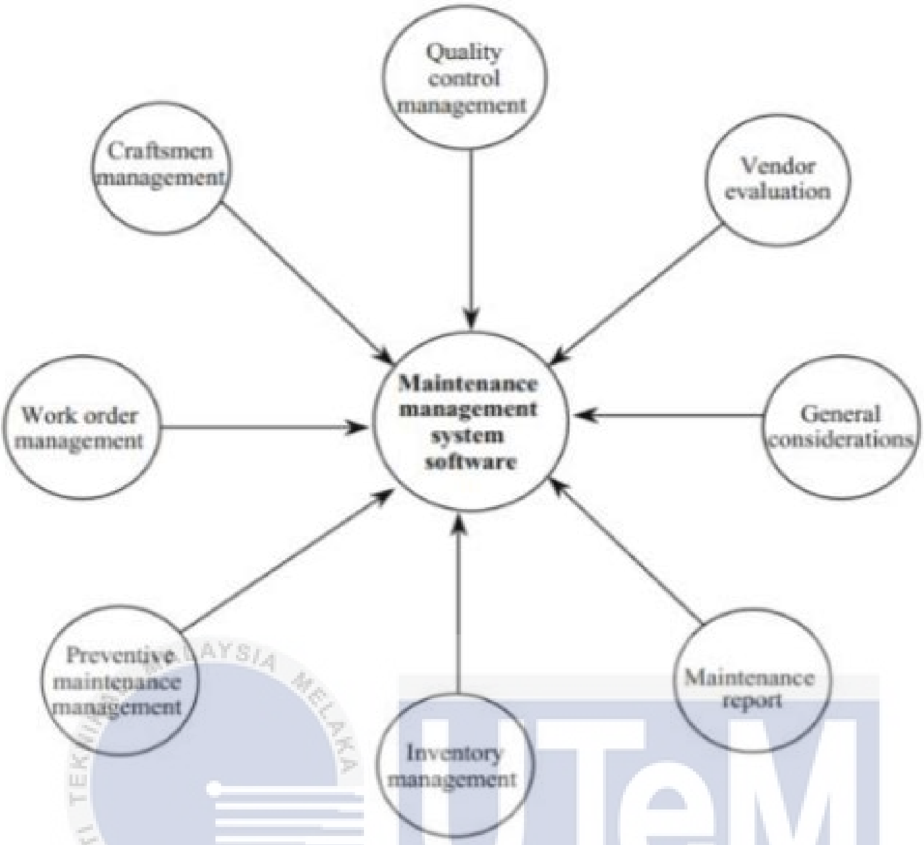

Figure 2. 6 Shows the functions of computerized maintenance management systems (Alshokry et al., 2021)

The work order is the initial step in the maintenance procedure. The process of adding a new work order to the CMMS differs from mining site to mining site and is contingent on the workflow of the firm(Robatto Simard et al., 2023). At one mining location where we conducted interviews, nearly all of the maintenance employees were able to provide a work order and then incorporate it into the system. Before being uploaded to the CMMS, work order requests that were filled out by an employee and submitted were checked and authorized by a designated member of the team at each other site that was the subject of an interview. The procedure for creating work orders is entirely contextual. Because the creation of some work orders may be automated, this allows us to delegate that responsibility to the system. The general superintendent will determine the permanent triggers for this process of creation, and they will be based on the maintenance plan that has already been developed. When a specific threshold is exceeded, the triggers will examine the total number of engine hours for a piece of equipment and add a preventative maintenance work order to the system.

Having stated that several key performance indicators may be used as triggers. It is beneficial to have recurring maintenance tasks, such as those requiring PM, automatically create work orders for them. There is also the option of manually putting together work orders. The establishment of a manual work order occurs most frequently either after a PM inspection carried out by the mechanic or after the operator has used the piece of equipment in question. The protocol for the generation of active work orders at the mine must, of course, be adhered to at all times. The process of creating work orders, in whatever way that may be done, is a vital step in ensuring that the amount of time spent waiting for equipment to be repaired is kept to a minimum. As a result, it is subject to stringent regulations. To maximize the effectiveness of maintenance planning and scheduling, the documentation and explanation of work orders must adhere to certain criteria. The prioritization of a work order is the aspect of these criteria that are considered to be the most significant(Robatto Simard et al., 2023).

2.8 Maintenance Cost Planning and Estimating

The maintenance cost includes all the expenses associated with bringing the building up to an acceptable level of quality. It refers to direct maintenance expenses, such as spares, labor, equipment, and tools, and indirect costs, such as administration, management, and unavoidable overhead expenditures(Le et al., 2018). When the maintenance demands are determined, an estimate of the maintenance cost should be performed as a preliminary step to gauge the availability of resources and determine how much work should be scheduled for each period. Even while it is common practice to develop cost estimates for building maintenance throughout a length of time to anticipate the expected cost of such works throughout the lifetime of the buildings, these costs can still be considered within the context of a single annual maintenance program(Le et al., 2018). The following list defines the primary goals a cost plan for building maintenance should accomplish Le et al., 2018).

- Identify the cost cap that should be targeted for the unkept of the program works.
- Input into determining the annualized maintenance budget and the availability of money constraints.
- Ensure that decision-makers have access to accurate cost information so that they may make educated choices.
- Specify which asset investments will be supported and which will not, then amend the plan for the total cost of the asset's life cycle.

Maintenance budgets, just like any other programs or plans, will be subject to change and revision, and they will need to be based on forecasting or predicting to aim for the most significant possible utilization of fixed maintenance resources to meet the fluctuating maintenance workload(Le et al., 2018). As shown in Figure 2.7, the sum of the costs associated with corrective maintenance and preventative maintenance constitutes the overall maintenance cost. If you have an effective strategy for preventative maintenance, you may cut the cost of corrective maintenance, which will get you closer to the optimal maintenance zone. The sweet spot is exactly where the two expenses cancel each other out. Once monies are allocated for the maintenance budget, sensible internal allocation of those funds at the operational level or locating this optimal zone is required to use these funds efficiently(Le et al., 2018).

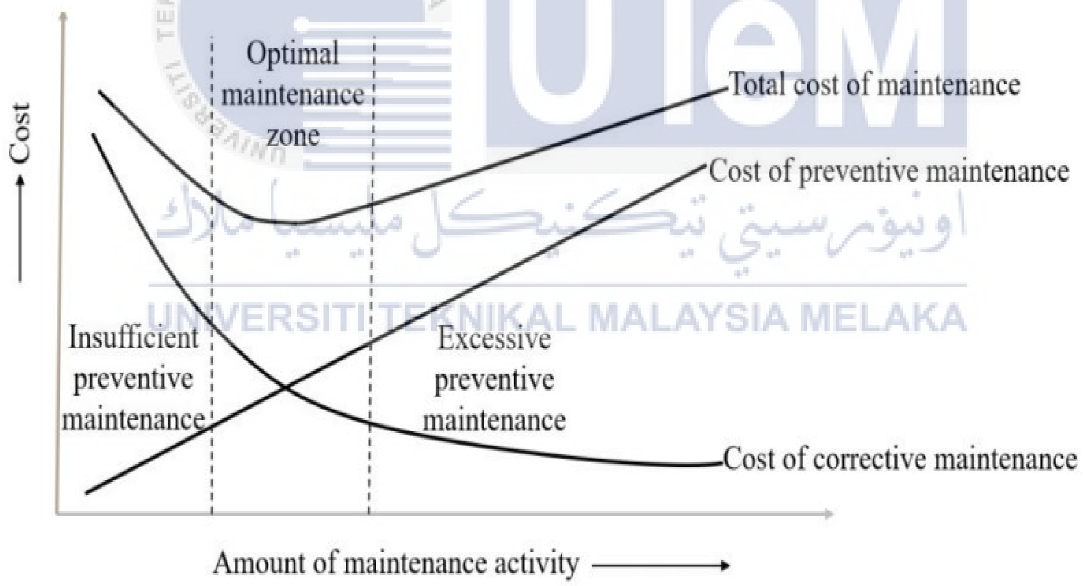

Figure 2. 7 Total maintenance cost (Le et al., 2018)

2.9 Air Handling Unit (AHU)

An Air Handling Unit (AHU) is an essential element in heating, ventilation, and air conditioning (HVAC) systems, specifically engineered to control and distribute air throughout a structure(Lun & Tung, 2020). AHU is a crucial component that serves as the primary hub for distributing conditioned air, ensuring optimal interior air quality and comfort. The system consists of many essential components, such as fans, filters, heating and cooling coils, dampers, and controllers. The main purpose of the AHU is to intake external air, purify and regulate it, and subsequently disperse it throughout the structure. This procedure entails the elimination of contaminants, such as particulate matter and noxious substances, guaranteeing a more salubrious and pleasant interior milieu(Lun & Tung, 2020).

AHU are available in a wide range of sizes and configurations to meet different HVAC needs, spanning from small residential units to expansive industrial systems. AHU are very adaptable and can effectively regulate temperatures in various climates by offering both heating and cooling functionalities. Moreover, sophisticated control systems provide accurate management of temperature, humidity, and air flow, thereby improving energy efficiency. Within commercial and industrial environments, AHU plays a crucial role in ensuring ideal working conditions, protecting equipment, and adhering to strict environmental regulations(Lun & Tung, 2020). To summarize, an air handling unit plays a crucial role in HVAC systems, making a substantial contribution to the quality of indoor air, thermal comfort, and the general performance of a structure.

2.9.1 Key Components of AHU

The operations of the AHU have a substantial effect on both the supply air temperature and humidity levels, as well as the energy consumption for heating, cooling, and ventilation. The operations of AHU have a significant impact on the energy consumption of buildings, the level of thermal comfort experienced by occupants, and their overall health. Furthermore, AHUs are used to regulate the intake of building ventilation, connecting the major heating, and cooling systems with specific areas within the building(Lun & Tung, 2020). To carry out ventilation tasks, a range of dampers are available for connection to air ducts, such as the return air duct, exhaust air duct, fresh air duct, and supply air duct.

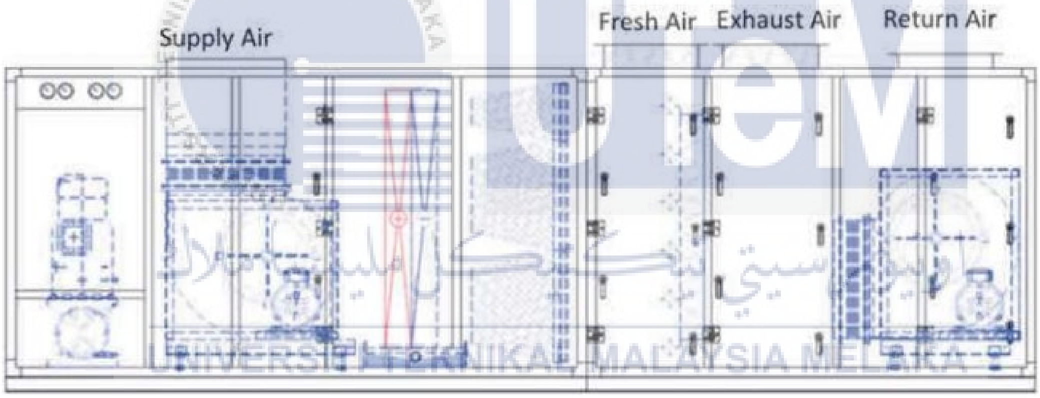

Figure 2. 8 AHU operations**(Lun & Tung, 2020)**

The primary classifications of heat pump systems include water-water, water-air, and air-air. Air distribution systems in HVAC systems commonly regulate the temperature and humidity of conditioned spaces by supplying air. The purpose of an AHU is to extract or introduce energy into airflows before delivering them to controlled environments. An AHU is responsible for distributing treated air to different conditioned areas within one or more zones. The essential elements of an AHU consist of fans, heating and cooling coils, and dampers. A direct-expansion (DX) AHU consists of refrigerant circuits that incorporate essential components such as a compressor and an expansion valve(Lun & Tung, 2020).

Figure 2.8 depicts the functioning of the AHU with a ventilation system. The AHU receives return air flow and expels some of it outdoors while introducing a specific quantity of new air into the system. After passing through the air filter, the blended air is directed. After passing through the heating and cooling coils, which regulate the temperature to ensure optimal thermal comfort indoors, the system delivers the conditioned air to the inside environment(Lun & Tung, 2020).

The primary purpose of an AHU, in addition to distributing air, is to provide air conditioning. There are two primary categories of central air-conditioning systems: water type and DX type. The air-conditioning system in the water type utilizes an integrated chilled water and hot water system. The DX type directly chills or heats the air by the refrigerant flowing through the cooling coil and heating coil of the AHU(Lun & Tung, 2020). Due to the direct cooling and heating of the air by the refrigerant, the DX plant exhibits improved cooling and heating efficiency, particularly for small and medium-sized plants. The efficiency of a chilled water system is better for large plants.

There are three primary categories for classifying heat pump systems: water-water, water-air, and air-air. The HVAC system regulates the air temperature and humidity by supplying conditioned air to the designated regions. The purpose of an AHU is to cool or heat the airstreams before delivering them to conditioned rooms(Lun & Tung, 2020). An AHU is responsible for distributing treated air to different conditioned areas within one or more zones. Essential elements of an AHU consist of fans, heating and cooling coils, and dampers.

2.10 Summary

The purpose of this study is to investigate the effects that preventive maintenance has on buildings. The phrase "preventive maintenance" refers to the actions of maintenance that are carried out at predefined intervals or according to prescribed criteria to lessen the likelihood of an item failing or degrading in its capacity to perform its intended functions. It intends to achieve these goals by doing routine inspections, diagnosing the state of the equipment, and taking preventative measures. The chapter delves into several distinct maintenance practices, including condition-based maintenance (CBM), predictive maintenance (PdM), and corrective maintenance (CM). PM refers to preventive maintenance procedures that are carried out on a machine when it is stopped to perform such procedures. PdM, which is a subset of PM, refers to maintenance that is carried out on a machine while it is being utilized. CM, which is also known as run-to-failure maintenance, is performed on an object once a problem has been found to return it to the function that is required of it.

The goal of predictive maintenance is to identify potentially catastrophic breakdowns in advance before they occur. Decisions about maintenance are made based on the information obtained through condition monitoring. CBM, a sort of predictive maintenance, is carried out based on the prediction that is produced from repeated analysis of available characteristics and evaluation of major parameters of degradation. This evaluation is done to determine when CBM should be carried out. The chapter also addresses the benefits and drawbacks of PM, CM, and CBM in detail. PM enables maintenance to be regulated, cuts down on unanticipated breakdowns, and contributes to cost control. CM has the potential to cause unexpected downtime that might be rather lengthy but also has the benefit of returning equipment to its intended use. CBM helps eliminate uncertainty and enables possible problems to be addressed before they do any harm to the product.

Any stoppage in production that was not scheduled is considered downtime. It encompasses both planned and unplanned downtime, the former of which refers to the period set aside in advance for activities like maintenance, breaks, and holidays, while the latter is the period that occurs as a direct result of unanticipated occurrences that disrupt productivity. The overall effectiveness of equipment, often known as OEE, is a statistic that may be used to evaluate the efficiency of both individual pieces of equipment and integrated equipment systems. The higher the OEE values, the better the cost savings and enhanced equipment efficacy will be. Planning preventive maintenance entails organizing resources to make certain that maintenance chores are carried out by time triggers or use triggers. Putting down a comprehensive PM schedule, considering who will carry out the task and at what intervals, is required. The key to successful PM scheduling is to have a concise maintenance plan, provide regular training for technicians and operators, carry out frequent inspections, and integrate the process with production. Several reasons, including a lack of preparation, limited resources, and ineffective communication, can contribute to ineffective PM scheduling.

The actions that are carried out in advance of conducting a maintenance task are referred to as preventive maintenance planning. These activities include determining the requirements in terms of material and labor, allocating time, and referencing technical knowledge. It is essential to have effective planning to guarantee that procedures are dependable and consistent and to prevent breaks in production.

In a nutshell, this chapter serves as an introduction to the research project and discusses a variety of topics about maintenance. These topics include the many categories of maintenance, downtime, overall equipment efficacy, preventive maintenance scheduling and planning, and more. The purpose of the study is to evaluate the influence that preventive maintenance has on buildings, and it highlights the need to study pertinent problems before performing a case study to get meaningful data.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will detail the approaches taken to achieve the research goals set for this study. The method of doing research is divided into two stages. The project's first stage consists of desk research, which comprises gathering and analyzing in-depth data derived from a comprehensive literature review on the impact of preventive maintenance at Complex C. In the second stage, the research methods are described by analyzing the data. This chapter focuses on and analyses the plan for preventive maintenance and the effectiveness of preventive maintenance.

3.2 Research Design

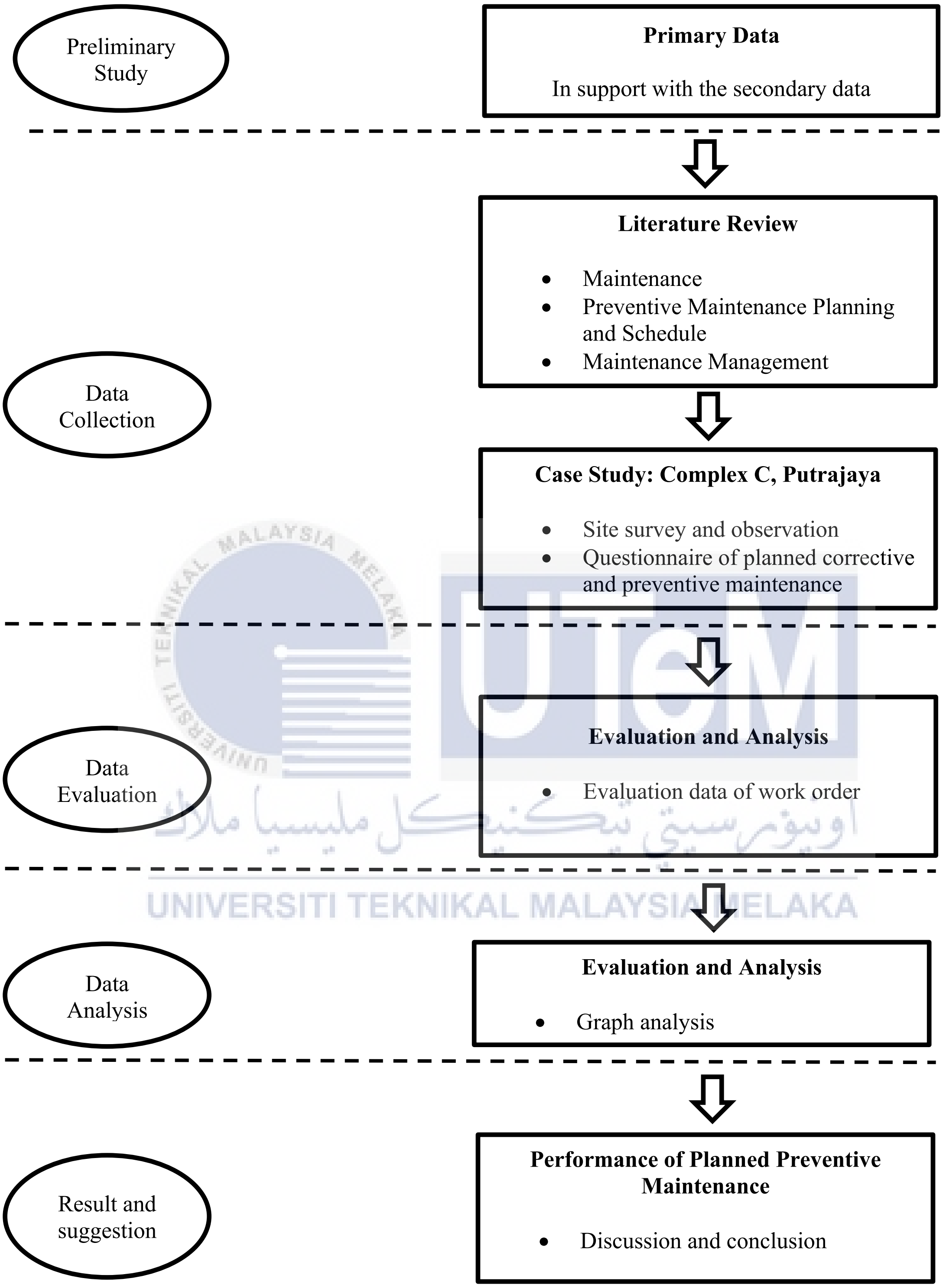

Figure 3. 1 General research framework

The diagram that can be seen in Figure 3.1 illustrates the overall structure of the project. To select the strategy most suited to the situation, the problem and the intended result were first established, and then a review of the pertinent literature was conducted. We assembled information on the quality of data reporting, the technique we would be using, and potential paths for correcting the concerns discovered in the literature study by reviewing relevant journals, books, and articles. This review of the research concentrates on preventative maintenance, planning and scheduling for preventive maintenance, and management of maintenance.

3.3 Flow Chart

In this section, the stage of the overall process of carrying out research will be discussed in detail. The flow chart and an explanation of the research technique are included in this section. These steps can serve as a guide for the researcher to begin and continue the research efficiently until the goals are achieved. The following is a step that was taken to address the issues that were found during this research:

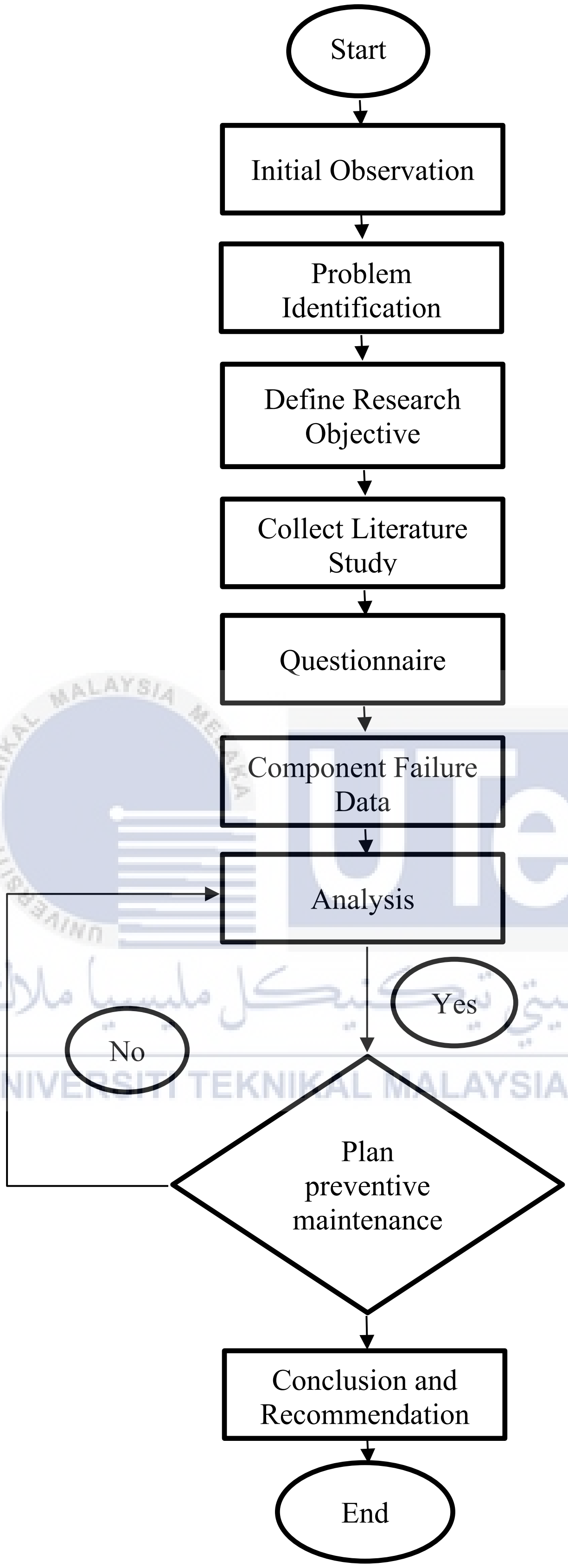

Figure 3. 2 Flow chart

3.4 Gantt Chart

3.4.1 Phase 1

GANTT CHART FINAL YEAR PROJECT

PROJECT TITLE: THE IMPACT OF PREVENTIVE MAINTENANCE ON BUILDING MAINTENANCE OUTCOMES: A CASE STUDY OF GOVERNMENT BULIDING IN PARCEL C AT PUTRAJAYA

SUPERVISOR'S NAME: TS. AHMAD NIZAM BIN JAMALUDIN

STUDENT'S NAME: MUHAMMAD HAZIM AIMAN BIN HAZMAN

NO	TASK TITLE	DURATION	ACADEMIC WEEK (2023-2024)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
CHAPTER 1: INTRODUCTION																
1.1	Background of Research	14 Days														
		56 Days														
1.2	Problem Statement	14 Days														
		56 Days														
1.3	Research Objectives	14 Days														
		56 Days														
1.4	Job Scope	14 Days														
		56 Days														
1.5	Significance of Study	14 Days														
		56 Days														
CHAPTER 2: INITIAL STUDY																
2.1	Literatre Review	56 Days														
		49 Days														
CHAPTER 3: RESEARCH METHODOLOGY																
Phase 1: Site Visit																
3.1.1	Identify the facilities in buildings	21 Days														
		35 Days														
3.1.2	Draft the questionnaire	14 Days														
		35 Days														
3.1.3	Collect the data	21 Days														
		35 Days														
3.1.4	Analysis data															
CHAPTER 4: PRE-RESULTS																
4.1	Preliminary Results	14 Days														
		14 Days														
OTHERS																
1	First of Submission Dissertation	1 Days														
		1 Days														
1.1	Logbook	1 Days														
		1 Days														
1.2	Presentation	1 Days														
		1 Days														
1.3	Final Submission of Dissertation	1 Days														
		1 Days														

Figure 3. 3 Gantt chart phase 1

The provided Gantt chart presents a 14-week research project that investigates the influence of preventive maintenance on building outcomes. The study specifically concentrates on a government building located in Putrajaya. The research is clearly organized into chapters, with the earliest weeks focused on establishing the foundation. Chapter 1 explores the research background, problem, objectives, scope, and significance. Chapter 2 provides a comprehensive examination of existing literature, while Chapter 3 outlines the research method. This chapter entails doing a site visit to ascertain the presence of facilities, formulating questionnaires, gathering data, and subsequently analyzing it. Chapter 4 outlines the preliminary findings, while the remaining weeks are allocated for dissertation submission, logbook maintenance, presentation preparation, and final dissertation submission. The chart emphasizes the coordination of work to optimize productivity and clearly designates important milestones, guaranteeing seamless project advancement. This research seeks to provide important insights into facility management methods by employing a case study approach that emphasizes preventive maintenance.

3.4.2 Phase 2

GANTT CHART FINAL YEAR PROJECT

PROJECT TITLE	THE IMPACT OF PREVENTIVE MAINTENANCE ON BUILDING MAINTENANCE OUTCOMES: A CASE STUDY OF GOVERNMENT BULIDING IN PARCEL C AT PUTRAJAYA
SUPERVISOR'S NAME	TS. AHMAD NIZAM BIN JAMALUDIN
STUDENT'S NAME	MUHAMMAD HAZIM AIMAN BIN HAZMAN

NO	TASK TITLE	DURATION	ACADEMIC WEEK (2023-2024)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Milestones																
Phase 2: Collect the data																
3.2.1	Site visit	1 Days														
		1 Days														
3.2.2	Distribute the questionnaire to the	21 Days														
		35 Days														
3.2.3	Identify the facilities in building	21 Days														
		35 Days														
Phase 3: Analysis data																
3.3.1	Analyse questionnaire	35 Days														
		49 Days														
3.3.2	Identify the facilities break down	35 Days														
		49 Days														
3.3.3	Identify sub-component of facilities break d	35 Days														
		49 Days														
3.3.4	Analyse component break down using RCA	35 Days														
		49 Days														
CHAPTER 4: RESULTS																
4.1	Results	21 Days														
		35 Days														
4.2	Discussion	21 Days														
		35 Days														
CHAPTER 5: CONCLUSION																
4.1	Conclusion	14 Days														
		21 Days														
4.2	Recommendation	14 Days														
		21 Days														
OTHERS																
1	First of Submission Dissertation	1 Days														
		1 Days														
1.1	Logbook	1 Days														
		1 Days														
1.2	Presentation	1 Days														
		1 Days														
1.3	Final Submission of Dissertation	1 Days														
		1 Days														

Figure 3. 4 Gant chart phase 2

This Gantt chart illustrates the "Impact of Preventive Maintenance on Building Maintenance Outcomes" over 14 academic weeks. The process is carefully divided into five essential stages: conducting thorough research and developing a robust methodology (phase 1), systematically gathering data through site visits, questionnaires, and identifying building facilities (phase 2), rigorously analyzing the collected information (phase 3), interpreting the results and discussing their importance (phase 4), and ultimately reaching insightful conclusions and providing practical recommendations (phase 5). Dividing each phase into manageable activities ensures the achievement of deadlines, such as dissertation submissions and presentations.

3.5 Initial Observation

The observation was carried out at building Complex C at Putrajaya department such as the Ministry of Science, Technology, and the Environment, as well as the Attorney General's Office, the Department of Environment, the Elections Commission, the Public Service Commission, the Government Projects Task Force, the Public Service Department, and the Survey Department. The daily use of Complex C in Putrajaya necessitates the availability of good management facilities. To ensure that the performance of the facility management is not compromised, the engineer is responsible for organizing the maintenance schedule. Unfortunately, the buildings in Complex C of Putrajaya have not adequately managed their maintenance activities. It is clear that there is a lack of a good plan for preventive maintenance, and they are ignoring the deadlines for corrective and preventive maintenance.

3.6 Problem Identification

In the field of facilities management, observation is used to locate the source of the problem. It is necessary to define the objectives and the parameters of this investigation. The goals are laid out in the first chapter. In the interest of amassing the required data and information, we will conduct interviews and conduct observations in the maintenance department. The activities related to maintenance have not been appropriately handled and ignored the deadlines for corrective and preventive maintenance. As a result, to prevent it, the organization needs to decide on a maintenance schedule that is both efficient and effective. It is also important to acknowledge the scope of the research. The buildings in Complex C of Putrajaya were focused. The observation and data were gathered from March 2023 to November 2023.

3.7 Study Literature

The relevance of this stage is in the collection of appropriate theoretical materials, such as books, journals, and other publications, that will support the analysis presented in Chapter 4. The most essential and helpful research from the field of literature is about maintenance management, preventive maintenance, preventive maintenance planning and scheduling, maintenance cost, and CMMS.

3.8 Data Collection

The gathering of data is the next step in the process of carrying out the research. The data that will be utilized is the maintenance data collected from buildings in Putrajaya's Complex C beginning in March 2023 and continuing through November 2023.

3.8.1 Questionnaire Design

In this area of research, constructing standardized questionnaires is one of the activities that take place. The information gathered during this stage is intended to be the primary source of information for the investigation. Obtaining preliminary information regarding how demographic data are dispersed among inhabitants is frequently the primary objective of survey questionnaires. This is because the data received will display the features of a natural population. In addition, this standard questionnaire aims to discover any beginning situations or circumstances that could be relevant to this study. Developing this questionnaire, the most critical aspect of this study, is particularly significant because it is essential to collect sufficient and pertinent data.

There are two portions to the standard questionnaire for this study:

- **Section A** asked questions concerning demographic data. The fundamental details examine the respondents' backgrounds, considered supplementary data for the research.

- **Section B** independent variables, as shown. Technically, the questions are based on how well the responder comprehends, knows, and behaves about planned preventive maintenance. This part will eventually be categorized as the study's primary data.

The respondent's response to the research question will be considered the most critical factor in this questionnaire. Technically, the survey comprised open-ended questions with a predetermined structure. Thus, open-ended questions were posed to the responders. As a result, the knowledge produced by this study may be quantified and evaluated. As a result, this questionnaire is set up to assess the data obtained.

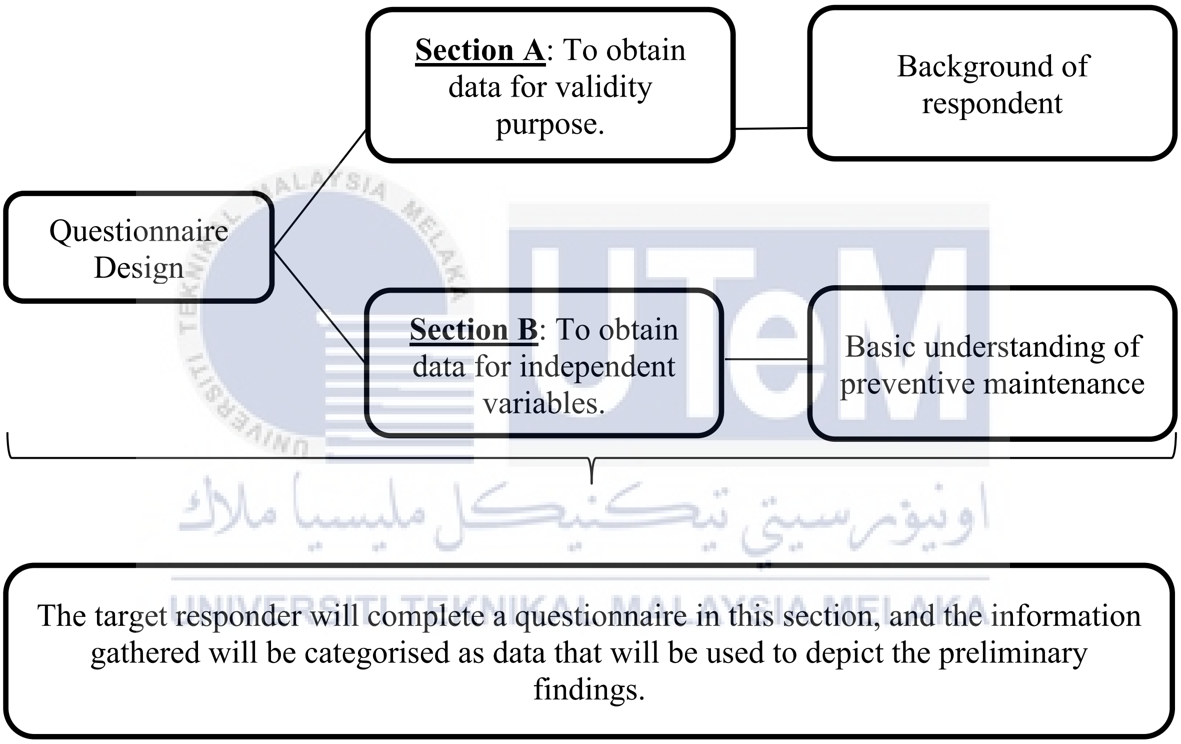

Figure 3. 5 Outline the content of the questionnaire.

3.9 Data Analysis

Following the completion of the data gathering and processing stages, there will be an investigation of the outcomes of the data processing. Pareto charts will be analyzed for critical components, and a proposed maintenance schedule will be carried out.

The methods for collecting data, the analysis, interpretation, and presentation of numerical data can all be handled using statistical procedures, which are mathematical approaches and solutions. As previously said, questions and data collection were used to collect the information for this study.

After that, a statistical process will be used to organize and analyze the acquired data. Descriptive statistics, which describe the properties of particular data and exhibit the data in tables or graphs for demonstration, will often come before statistical analysis in this course.

3.9.1 Pareto Chart

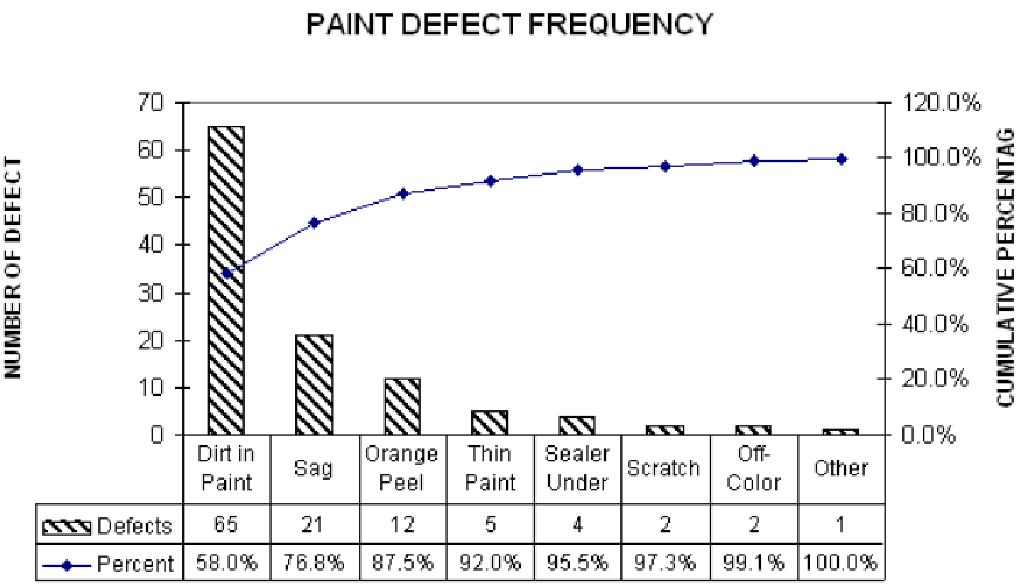

Figure 3. 6 The example of Pareto chart (Fajri, 2017)

The Pareto chart was first established by an Italian economist named Vilfredo Pareto and is a tool used to determine which aspects of a product or condition require the most urgent attention in terms of quality control and improvement(Fajri, 2017). The goal of the Pareto chart is to identify the issue currently taking up the most significant amount of time and effort. The Pareto chart illustrates which of our problems should be tackled first to reduce the number of instances of failure and enhance our operations. First, we will address the problematic goods that appear most frequently, then move on to the second-highest defective item, and so on.

A Pareto chart is a specific form of bar graph that helps visualize and analyze data to prioritize and focus on the most significant contributing factors or categories to a problem or situation. Analysis indicates that approximately 20% of the downtime factors contribute 80% of total downtime.

A Pareto chart's primary purpose is to provide a distinct and visual representation of the relative importance of various factors or categories based on their frequency or impact. It enables the identification of the critical few factors that account for the majority of a system's problems, inefficiencies, or opportunities.

A bar graph known as a Pareto chart is used to graphically portray data to prioritize the most critical elements or categories that are contributing to an issue or scenario. Ordering the parts in descending order of frequency or impact helps highlight the critical few components that account for the majority of the challenges or opportunities. The graphic gives a clear picture of the distribution of factors. It facilitates data-driven decision-making by concentrating attention and resources on the top few categories with the greatest influence. The most substantial gains can be made by companies when they pay attention to these critical variables and address them. This can be done with the fewest amount of resources and the least amount of work.

3.9.2 Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is a commonly employed method for determining the fundamental reason behind equipment malfunctions. The primary objective is to minimize expenses, mean time to failure (MTTF), and mean down time (MDT) for the organization. Effective execution of RCA can result in substantial financial savings or even the total eradication of a failure. Through investigating the failure, it becomes feasible to avert future failures by holding the underlying cause accountable for the initial failure. The primary objective of RCA is to discover and eliminate the underlying causes of equipment failure, including physical, human, or latent system factors. The primary objective is to reduce the likelihood of failure by focusing on corrective actions that address the underlying cause. RCA is a method used to identify and resolve problems by analyzing events that have already taken place. It is a reactive approach to problem detection and resolution.

A cause-and-effect diagram, also referred to as a "fishbone" diagram, is a useful tool for brainstorming and categorizing the causes of an issue(Lawrence Kau, 2016b). A fishbone diagram is a graphical representation that allows for the examination of the relationship between causes and effects. Compared to previous tools like the Five Whys tool, it offers a more organized and systematic technique for brainstorming the origins of a problem. At the head or mouth of the fish, the tool displays the problem or effect. The smaller "bones" contain a list of potential factors that may contribute to the causes, organized into different categories. The use of a fishbone diagram can facilitate the identification of potential explanations for an issue that may not be initially contemplated by guiding the team to examine the various categories and contemplate alternate causes. Ensure that the team includes members who possess firsthand knowledge of the procedures and systems relevant to the problem or occurrence under investigation(Lawrence Kau, 2016b).

3.10 Summary

In Chapter 3, a systematic framework is presented for analyzing and implementing a preventative maintenance program in building Parcel C Putrajaya. The research methodology in this study employs a systematic strategy that starts by identifying the problem and transforming it into research questions. Secondary sources are employed to conduct a comprehensive literature assessment on preventive maintenance, maintenance plans, and methodologies. Initial inspections at the lake maintenance center reveal concerns over corrective maintenance and the lack of a carefully devised plan for preventive maintenance.

Following that, interviews and observations are carried out to pinpoint maintenance issues in the regions of the Parcel C building that experience a high frequency of breakdowns. The research aims to provide a preventive maintenance programme with the goal of enhancing the ecological well-being and functionality of the area. The literature study focuses on relevant topics, specifically maintenance management, preventive maintenance, and maintenance costs. Data collection involves obtaining detailed observations and measurements, which includes gathering equipment data from the maintenance department and conducting interviews with the responsible individual. In order to collect qualitative data, a questionnaire is created, and the analysis involves using Pareto charts and statistical approaches. The results will provide the foundation for the creation of a maintenance schedule proposal.

The use of a data analysis tool is crucial for identifying the main aspects that contribute to failures. The purpose of this tool is to prioritize issues by identifying the ones that necessitate quick attention, therefore minimizing downtime and enhancing operations. The Pareto chart is a graphical depiction of the cumulative percentage of causes, which effectively shows the most frequent and critical concerns. The generation of a Pareto curve entails the gathering and categorization of interventions, the calculation of their proportions, and the production of a graphical representation. In addition, the RCA method will also be employed to determine the underlying reason for the equipment failure in Parcel C Putrajaya.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the culmination of research conducted for this final year project, delving into the analysis and interpretation of the obtained results. This section will include an analysis of the data on the plan preventive and corrective maintenance of building Complex C Putrajaya, as well as an analysis of the surveys that were carried out. Included in this area will also be the results and discussion of the data collected. The objectives of this section are to provide a solid scientific reason for the facts that were obtained and to discover the findings of the inquiry that was presented earlier.

4.2 Data Collection

Certain information and data that have been obtained from the observation are used as the basis for the data-gathering process. An explanation of the data that is necessary to carry out a plan of preventive and corrective measures for this research will be provided in this section. All of these facts are required at the beginning of the research process in order to determine the source of the problem and locate a solution to it.

4.2.1 Data Analysis

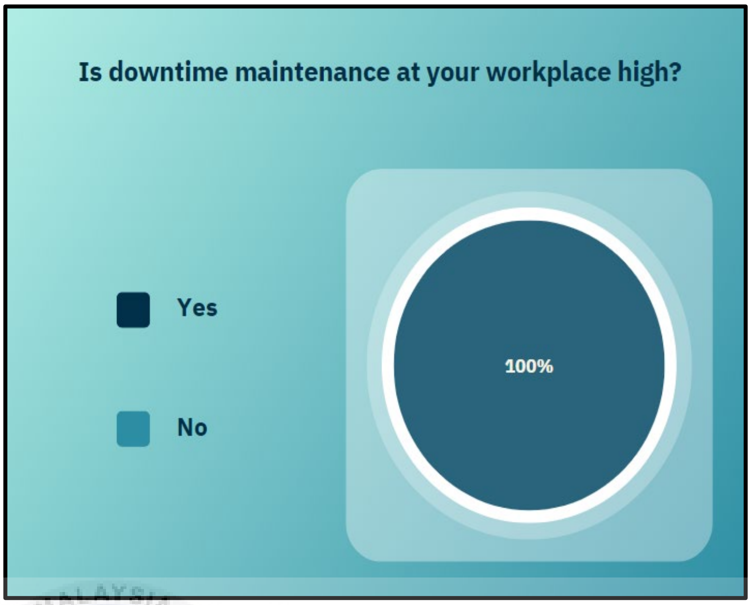

Figure 4. 1 Downtime maintenance at workplace

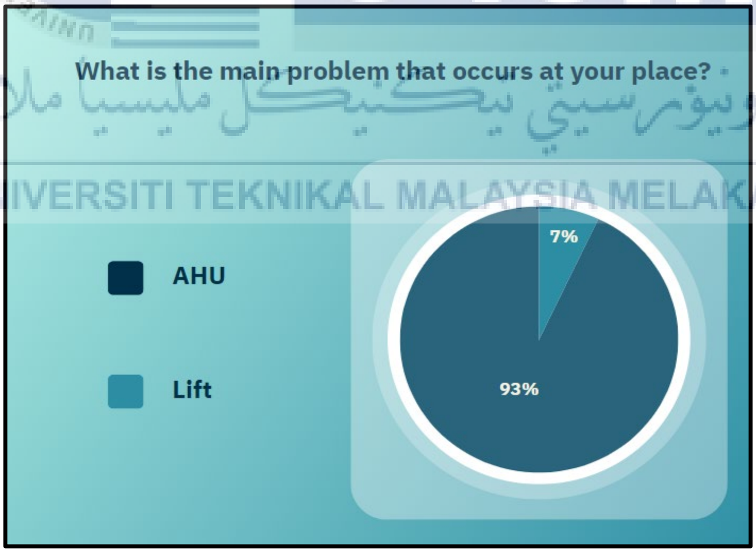

Figure 4. 2 Main problem at workplace

According to the survey data that was collected, the amount of maintenance downtime that has occurred at building Complex C Putrajaya has significantly increased. This may mostly be linked to problems with the Air Handling Units (AHU). A substantial obstacle has been presented as a result of the increased frequency of maintenance events related to AHU, which affects the overall continuity of operations. In order to guarantee that the AHU is operating correctly, which is essential for preserving the quality of the air within and the conditions of the surrounding environment, careful attention is required.

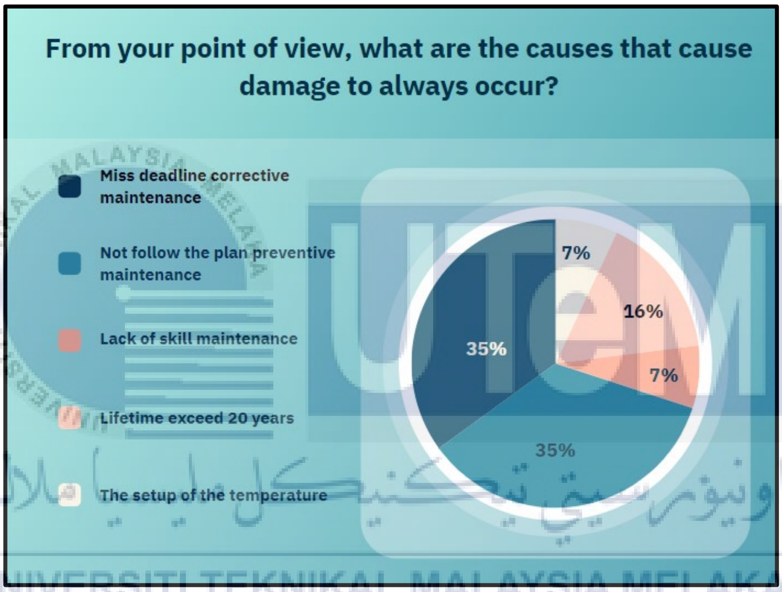

Figure 4. 3 The causes that cause damage to always occur

The dataset reveals a number of interesting trends, one of which is the association between the amount of time that maintenance downtime occurs and the skill levels of technicians. Similarly, respondents pointed out that downtime events tended to last for a longer period when they were handled by technicians who lacked specialized expertise in AHU maintenance. Because of this association, it is essential to make investments in technical training programs in order to improve the knowledge of the workforce that is responsible for maintenance.

The collected data from the survey also reveals a concerning trend in terms of compliance with the scheduled maintenance actions. The data revealed that 35% of the respondents admitted not following planned maintenance schedules. The stated justifications for this divergence encompassed constraints on resources and competing goals. The inconsistency in following stated goals directly impacts the longevity and reliability of AHU, thereby leading to a rise in unplanned periods of inactivity.

Figure 4. 4 New preventive and corrective plan required at workplace

According to the findings of the survey, in order to solve the ongoing problem of maintenance downtime in AHU, it is necessary to devise a comprehensive strategy that includes both preventive and corrective actions. Because of the existing issue, a systematic overhaul is required in order to improve the overall reliability of the system and reduce the number of unexpected disruptions. The development of a new maintenance plan that includes routine inspections, predictive analytics, and preventive maintenance is an example of a proactive strategy. The goal of this method is to identify and address any problems before they become more severe. By using this preventive maintenance framework, the aim is to maximize the performance of the equipment, increase the lifespan of the components, and prevent unscheduled downtimes. At the same time, a comprehensive corrective maintenance plan should be developed, with an emphasis on prompt response and effective troubleshooting, with the goal of reducing the amount of time that the system is offline in the event of unforeseen failures.

4.2.2 Identification of Total Breaks Down of Facilities

In the following table 4.1, the frequency of break facilities at buildings in Complex C of Putrajaya is displayed. These break down facilities begin in March 2023 and continue until November 2023. For the purpose of determining which component is essential and requires additional investigation, the information presented in the figure serves as a core piece of information.

Table 4. 1 The Frequency of breaks down of facilities at buildings in complex C at Putrajaya

No.	Facilities	Frequency of Breaks Down	Downtime (hours)
1	Water tank	1	18.75
2	AHU	108	16693.95
3	Fire fighting system	13	2.8
4	Pump	21	238.27
5	Lift	53	276.63

Pareto chart is a common method to be used in the research to identify the most critical breakdown that exists based on the data collection. Below is the Pareto chart from the frequency of breaks down at buildings in Complex C of Putrajaya.

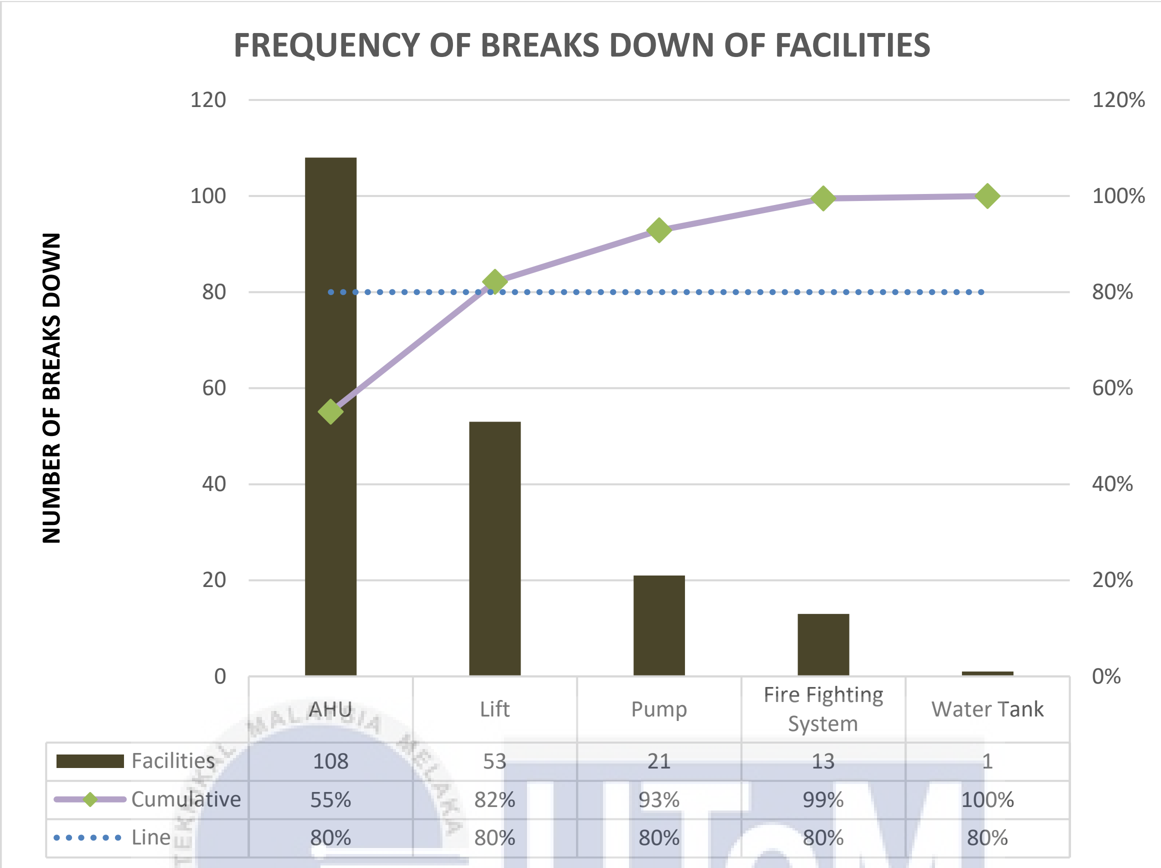

Figure 4. 5 Frequency of breaks down facilities at buildings in complex C at Putrajaya (March 2023 - November 2023)

According to Figure 4.1, the AHU has seen the highest number of breakdowns, accounting for 108, or 55%, of the total breaks in facilities located in Complex C at Putrajaya. The number of lift breakdowns in Complex C at Putrajaya is 53, which accounts for 27% of the total. Pump failures accounted for 21 breakdowns or 11%. AHU accounts for approximately 55% of the malfunctions that arise in facilities situated in Complex C in Putrajaya.

4.2.3 Identification of Component AHU

The next step in this research is to establish which components of the AHU break down the most frequently. This is done after the critical breakdowns of facilities at buildings in Complex C at Putrajaya, involving the AHU, have been identified. In the following table 4.2, the frequency of breaks down facilities at buildings in Complex C of Putrajaya is displayed beginning in March 2023 and continuing until November 2023.

Table 4. 2 The frequency of components failure in AHU

No.	Component	Frequency of Failure	Downtime (hours)
1	Fire damper	20	457.18
2	Indicator light	24	381.5
3	Motor bearing	10	14878.55
4	Filter	31	464.15
5	Chilled water pipe	6	133.92
6	Cooling coil	4	97.38
7	Belting	4	70.13
8	AHU Leaking	2	72.3
9	Fan	7	138.85

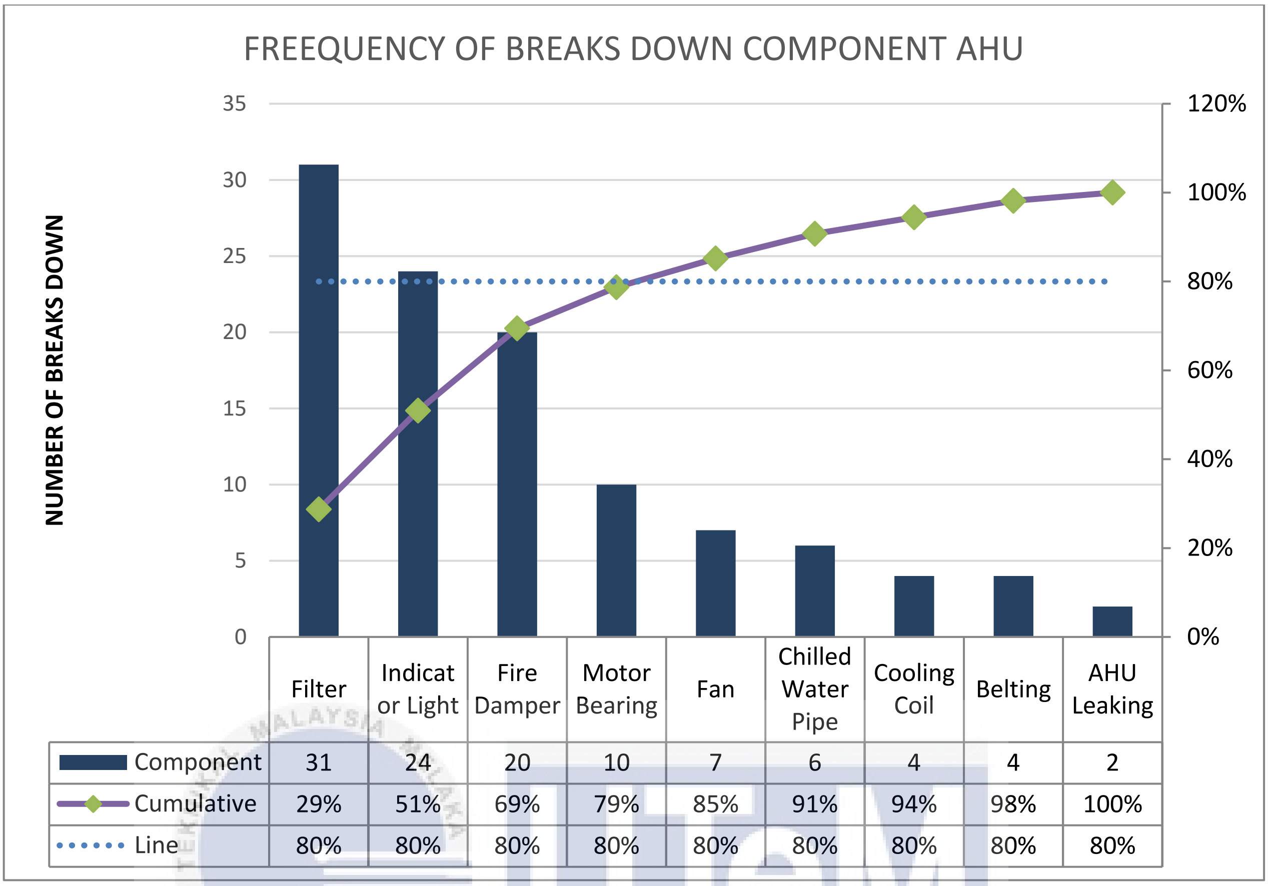

Figure 4. 6 Frequency of breaks down component AHU

Based on Figure 4.2, the AHU filter is the most crucial element, accounting for 31 instances or 29% of the total AHU failures. The indication light falls in the AHU 24 times, which accounts for 22% of the overall occurrences. Similarly, the fire damper fails in the AHU 20 times, making up 19% of the total occurrences. In addition, there are ten failures in the motor bearing, which make up 9% of all failures in the air handling unit. Figure 4.2 identifies the filters, indicator lights, motor bearings, and fire dampers as the four key components of the AHU. Those four components are accountable for 79% of the breakdowns in the AHU and contribute to the cessation of system operation.

For the purpose of determining the impact of the failure of the facilities system that was brought about by those components, the downtime of the facilities systems consists of complementary data. In the event that the facilities system is unavailable, the output of the system in building Complex C at Putrajaya will be impacted. If the downtime continues for a longer period than it did in the past, it will result in the losses that the company has earned becoming even more significant. The downtime that occurs as a result of the facility breakdown is anticipated to be reduced by the preventive maintenance activity.

4.3 Root Cause Analysis (RCA)

The Air Handling Units (AHU) at Complex C Putrajaya are of utmost significance in terms of ensuring that the climate is controlled and that the quality of the air inside the building is preserved. If one of the components that make up the AHU experiences a malfunction, it has the potential to cause the entire system to become problematic. A filter, an indicator light, a fire damper, and a motor bearing are some of the components that break down more, according to the Pareto chart.

4.3.1 Filter

Figure 4. 7 Filter in AHU

The failure of the filter component that is contained within the AHU on multiple occasions is the root cause of the problem. This failure not only puts the air filtering process at risk but also sets off a domino effect that affects the entire air handling system, which in turn affects the conditions of the indoor environment. Filters in an AHU are to ensure the delivery of clean and healthy indoor air by removing particles, contaminants, and pollutants.

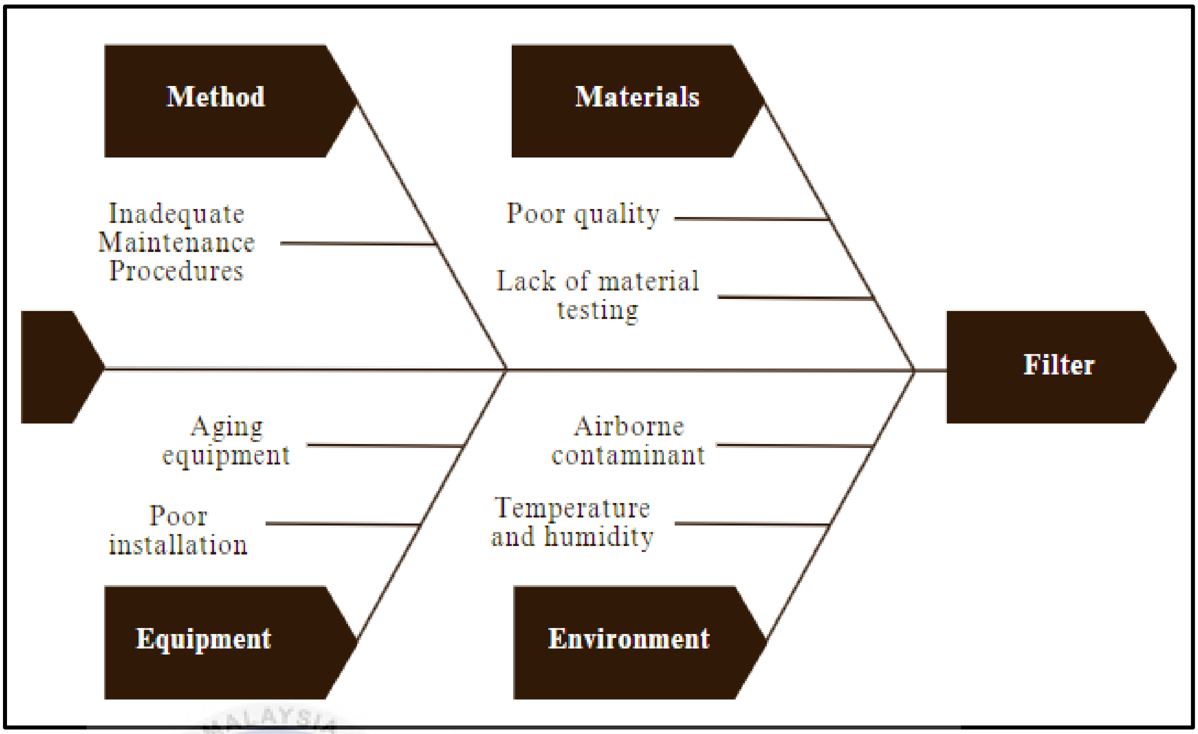

Figure 4. 8 Fishbone of filter

According to the findings of the investigation, the immediate cause was the physical breakdown of the filter element of the device. Following further investigation, a number of relevant factors were identified. These factors included the quality of the materials that were utilized, the operational circumstances, the maintenance methods, and environmental impacts. The identification of the underlying reasons requires a thorough comprehension of these symptoms.

Table 4. 3 Changes for improvement of filter

No.	Major Cause	Root Cause	Changes of Improvement
1	Material: 1. Poor quality 2. Lack of material testing	1. The use of low-quality filter material that is prone to premature breakdown. 2. Failure to test filter materials for compatibility with AHU operating conditions.	1. Collaborate with suppliers to ensure the use of high-quality materials meeting industry standards. 2. Implement a testing protocol for all incoming filter materials to ensure compatibility.
2	Method: Inadequate maintenance procedure	Lack of a systematic and regular maintenance schedule for filter inspection and replacement.	Provide training for maintenance personnel to enhance their understanding of critical components and potential failure indicators.
3	Equipment: 1. Aging equipment 2. Poor installation	1. Filters or filter-related components reaching the end of their expected lifespan. 2. Incorrect installation of filters, causing stress on the material and reducing effectiveness.	1. Develop a proactive equipment replacement plan based on the manufacturer's recommendations. 2. Conduct a review of installation procedures and provide additional training to personnel.
4	Environment: 1. Airborne contaminant 2. Temperature and humidity	1. Presence of excessive dust, pollutants, or airborne contaminants in the environment, leading to quicker filter clogging. 2. High or fluctuating temperatures and humidity levels cause degradation of filter material.	1. Implement additional pre-filtration systems or air purifiers to reduce the load on the main AHU filters. 2. Install environmental controls or climate regulation systems to maintain stable temperature and humidity levels within the AHU room.

Based on Table 4.3, inadequate indoor air quality in AHUs may be caused by a variety of factors. It is feasible to enhance indoor air quality and establish a more health-conscious environment for occupants by implementing environmental controls, material selection, maintenance procedures, and equipment conditions.

Filter quality within the AHU is important. According to the data presented in Table 4.3, employing filters of inferior quality or those that are incompatible with the operating conditions of the AHU may result in untimely failure and compromised air quality. Collaboration with suppliers to ensure the use of high-quality materials that adhere to industry standards and the implementation of a testing protocol for all incoming filter materials to ensure compatibility are among the suggested improvements.

Following this are the maintenance procedures for the AHU. Inadequate air quality may result from the absence of a systematic and routine maintenance schedule for filter inspection and replacement, according to Table 4.3. An enhancement should be implemented to provide maintenance personnel with training to enhance their comprehension of critical components and potential indicators of failure.

Additionally, this pertains to the state of the AHU itself. According to the data in Table 4.3, improperly installed filters or aging equipment may reduce the efficiency of the AHU and result in poor air quality. Developing a proactive equipment replacement strategy in accordance with the manufacturer's guidelines, undertaking a review of installation procedures, and providing personnel with additional training are among the suggested enhancements.

Finally, this pertains to the air quality that is introduced into the AHU. Table 4.3 indicates that an environment containing an excessive amount of dust, pollutants, or airborne contaminants may accelerate filter obstruction and degrade air quality. The suggested modifications for enhancement encompass the integration of supplementary pre-filtration systems or air purifiers to alleviate the burden on the primary air handling unit (AHU) filters, as well as the installation of environmental controls or climate regulation systems to ensure the AHU room maintains consistent temperature and humidity levels.

4.3.2 Indicator Light

Figure 4. 9 Indicator light

In AHU, indicator lights are vital parts that provide crucial information about the state and functionality of the system. Operational difficulties and possible system failures may arise when these indicator lights malfunction or show false information. Following further investigation, a number of relevant factors were identified. These factors included the flickering lights, inconsistent readings, or the complete failure of indicator lights to function.

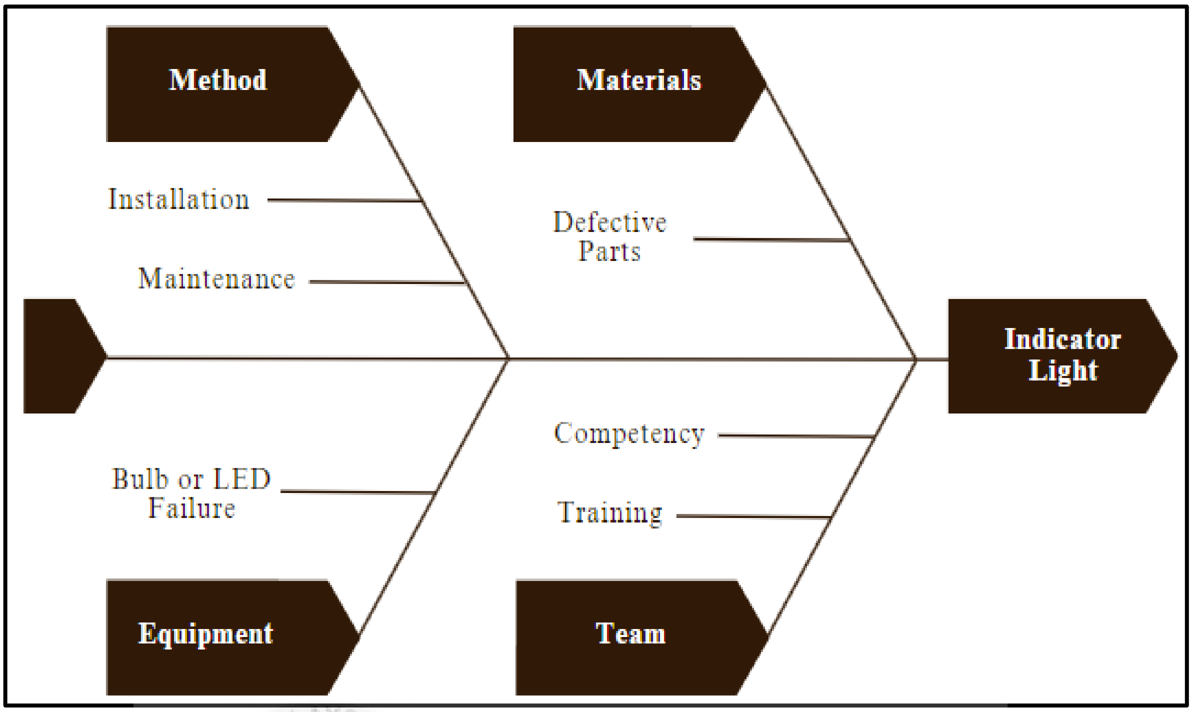

Figure 4. 10 Fishbone of indicator light

According to the findings of the investigation, the immediate cause was the physical breakdown of the indicator light. Following further investigation, a number of relevant factors were identified. These factors included the materials that were utilized, the equipment circumstances, the maintenance methods, and the team. The identification of the underlying reasons requires a thorough comprehension of these symptoms.

Table 4. 4 Changes for improvement of indicator light

No.	Major Cause	Root Cause	Changes of Improvement
1	Material: Defective parts	Faulty components or materials used in the indicator light assembly.	Implement a rigorous quality control process during the manufacturing of indicator lights to identify and eliminate defective parts.
2	Method: 1. Installation 2. Maintenance	1. Incorrect installation procedures could lead to the indicator light not functioning correctly. 2. Lack of regular maintenance or improper maintenance procedures.	1. Review and update installation procedures for the indicator light. 2. Develop a comprehensive maintenance schedule for the indicator lights in the AHU.
3	Equipment: Bulb or LED failure	The indicator light's bulb or LED may have burned out.	Implement a schedule for regular inspections of indicator lights to detect early signs of bulb or LED failure.
4	Team: 1. Competency 2. Training	1. The team might lack the necessary skills or knowledge to install or maintain the indicator light properly. 2. Insufficient training of team members regarding AHU indicator light systems.	1. Provide comprehensive training programs for the team members responsible for AHU maintenance. 2. Develop and implement a structured training schedule that includes regular updates on AHU indicator light systems.

Based on Table 4.4, one major culprit behind indicator light malfunctions is the use of faulty materials or inadequate manufacturing processes. Substandard components, improper assembly, or even errors during material selection can lead to premature wear and tear, electrical short circuits, or even complete system breakdowns. To address this, a rigorous quality control process throughout the manufacturing chain is indispensable. Implementing stringent testing procedures and employing high-quality materials can significantly reduce the risk of material-related failures.

Inadequate maintenance and installation is an additional frequent cause of indicator light malfunctions. Misconformities may result from improper wiring, insufficient mounting, or the omission of routine inspections. To counteract this, it is essential to implement a structured maintenance schedule that includes routine inspections, establish clear and exhaustive installation procedures, and provide comprehensive training for personnel accountable for maintenance. Preventing prospective problems from becoming complete failures is possible with the aid of proactive maintenance.

Although the indicator light appears to be a straightforward component, it can also give rise to complications. Particularly prevalent are LED and bulb burnouts and burnouts in systems that operate at high temperatures or are in continuous use. To address this, it is essential to use long-lasting, high-quality bulbs and LEDs. Furthermore, the introduction of routine inspections and replacements in accordance with the guidelines provided by the manufacturer can effectively reduce the likelihood of unforeseen power failures.

Lastly, failures may also be caused by team members who are tasked with the maintenance of the indicator light system possessing insufficient knowledge or abilities. This may arise from insufficient training, obsolete information, or inadequate protocols. In order to tackle this issue, it is imperative to offer exhaustive training programs that cover the correct procedures for installing, maintaining, and troubleshooting the particular indicator light system. Furthermore, ensuring that team members are informed of any developments or modifications in the system can guarantee that their understanding remains current and efficient.

4.3.3 Motor Bearing

Figure 4. 11 Motor bearing

The bearings of the motor are one of these components that play a significant role in ensuring the longevity of the system as well as the effectiveness of the system. Motor bearings support, align, and facilitate the smooth rotation of the motor shaft while minimizing friction and wear.

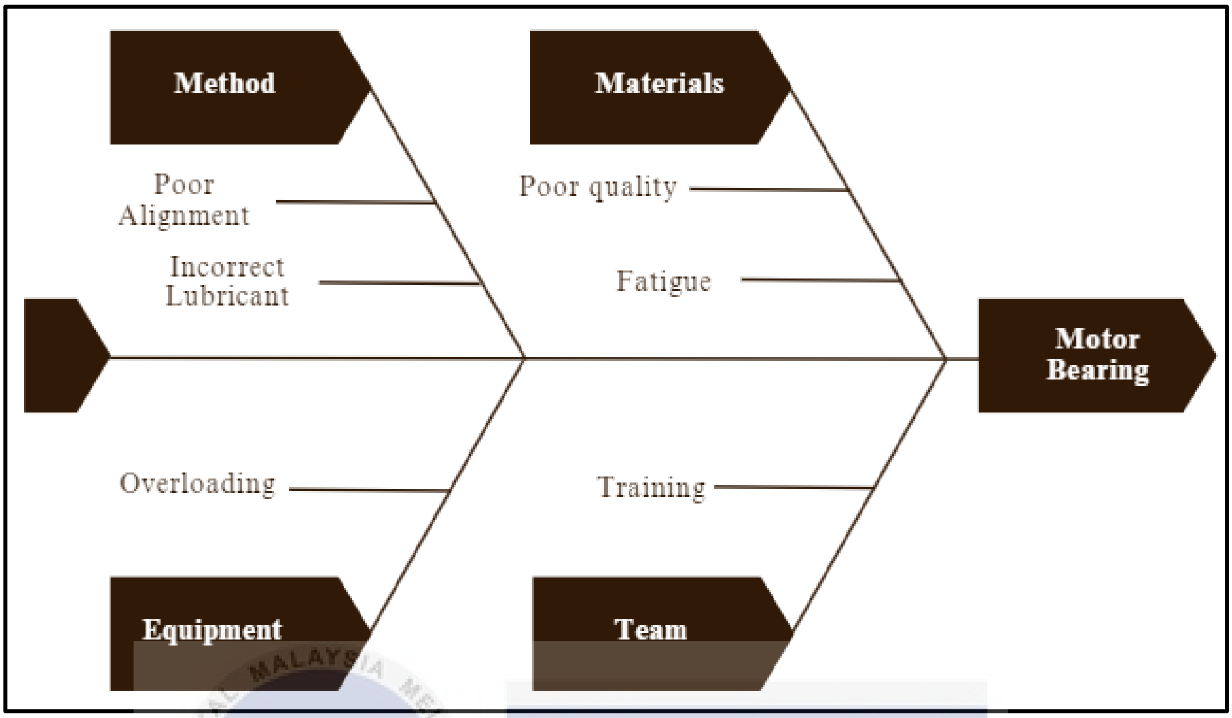

Figure 4. 12 Fishbone of motor bearing

According to the findings of the investigation, the immediate cause was the physical breakdown of the motor bearing. Following further investigation, a number of relevant factors were identified. These factors included the materials that were utilized, the equipment circumstances, the maintenance methods, and the team. The identification of the underlying reasons requires a thorough comprehension of these symptoms.

Table 4. 5 Changes for improvement of motor bearing

No.	Major Cause	Root Cause	Changes of Improvement
1	Material: 1. Poor quality 2. Fatigue	1. The use of low-quality materials in bearing construction can lead to premature failure. 2. Frequent start-stop cycles or rapid changes in load can contribute to material fatigue in the bearings.	1. Collaborate with suppliers to ensure that bearings meet or exceed required standards. 2. Implement load management strategies to reduce the number of load cycles.
2	Method: 1. Poor alignment 2. Incorrect lubricant	1. Incorrectly aligning the motor during installation can lead to misalignment issues and subsequent bearing damage. 2. Using a lubricant that is not suitable for the motor's operating conditions can result in inadequate protection for the bearings.	1. Perform precision alignment during installation and regular maintenance to ensure proper alignment of motor components. 2. Verify that the lubricant used is compatible with the equipment and operating conditions.
3	Equipment: Overloading	The motor is being used beyond its rated capacity, leading to increased stress on the bearings.	Ensure that equipment is appropriately sized for the intended load.
4	Team: Training	Specialized training in motor maintenance, including bearing care, is necessary to address complex issues effectively.	Invest in continuous training programs to keep maintenance teams updated on the latest technologies and best practices.

The material composition of any bearing is fundamental to its quality. As appropriately highlighted in Table 4.5, the utilization of substandard materials can result in untimely bearing failure. This underscores the significance of establishing partnerships with dependable suppliers who place a premium on materials that meet or surpass the standards set by the industry. Furthermore, the enforcement of rigorous quality control protocols throughout the bearing manufacturing process can serve to enhance the assurance of material specification adherence.

Furthermore, bearing performance and lifespan can be fatally compromised by improper installation and insufficient maintenance procedures. Misalignment and improper lubrication are identified as the two largest problems in the table. For uniform load distribution and to prevent premature deterioration, precise alignment during installation is vital. In order to minimize friction and heat generation, thereby prolonging the life of bearings, routine maintenance inspections, which include lubrication with compatible lubricants appropriate for operational conditions, are of equal significance.

Furthermore, exceeding the designated capacity of a motor results in excessive strain on its bearings, which expedites the process of deterioration. The table underscores the importance of selecting equipment that is suitably sized for the intended burden. By maintaining the bearings at their designated capacity, this practice effectively mitigates preventable damage and minimizes disruption.

Lastly, bearings must be maintained in an ideal condition, which requires a skilled labor force. The importance of specialized training in motor maintenance, including appropriate bearing care techniques, is highlighted in the table. Providing personnel with ongoing training programs that incorporate the most recent knowledge and optimal methodologies empowers them to address intricate bearing concerns proactively and efficiently for long-term system reliability and efficiency. Regular monitoring, training, and adjustments based on performance data contribute to a proactive and sustainable maintenance strategy.

4.3.4 Fire Damper

Fire dampers are an essential component in the process of guaranteeing the safety of buildings by preventing the spread of smoke and fire through heating, ventilation, and air conditioning (HVAC) systems. The failure of these dampers in AHU to perform properly poses a substantial risk to the occupants of the building as well as to the property.

Figure 4. 13 Fire damper

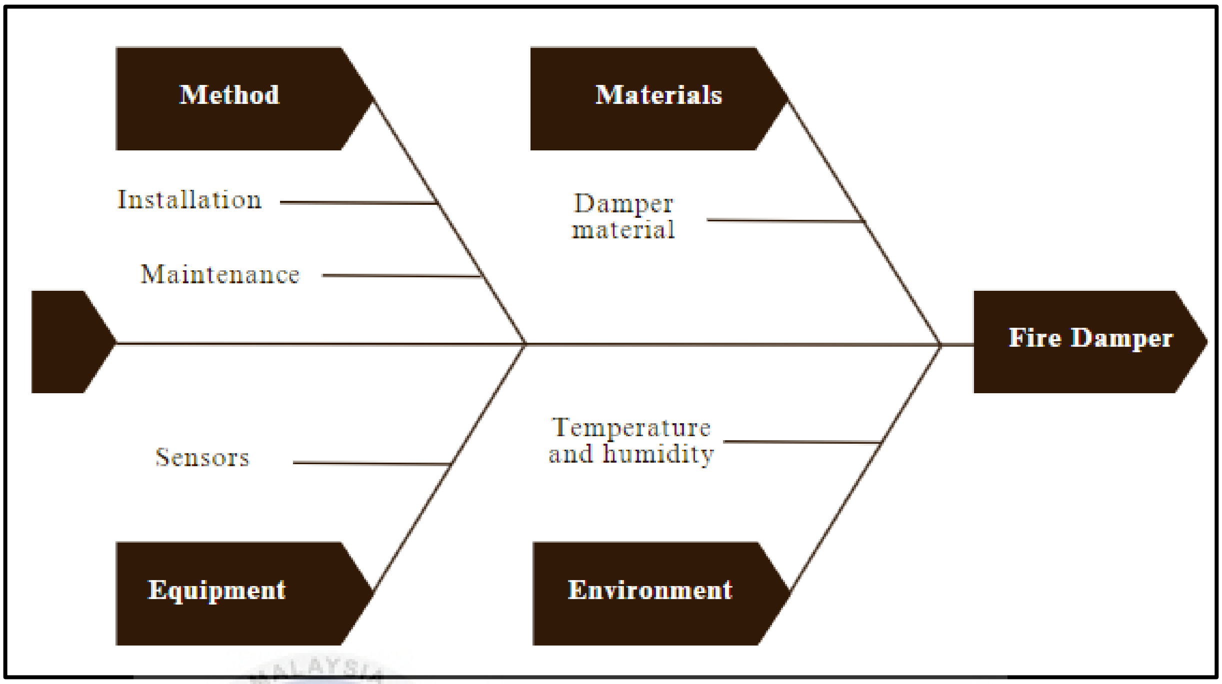

Figure 4. 14 Fishbone of fire damper

Following further investigation, a number of relevant factors were identified. These factors included the quality of the materials that were utilized, the operational circumstances, the maintenance methods, and environmental impacts. These are some of the potential problems that could arise. The identification of the underlying reasons requires a thorough comprehension of these symptoms.

Table 4. 6 Changes for improvement of fire damper

No.	Major Cause	Root Cause	Changes of Improvement
1	Material: Damper material	The damper's material has degraded over time, affecting its overall performance.	Select materials with better corrosion resistance for damper construction.
2	Method: 1. Installation 2. Maintenance	1. The damper was not installed correctly, leading to misalignment and operational issues. 2. Insufficient maintenance procedures have allowed for the deterioration of critical components over time.	1. Ensure proper installation by following manufacturer guidelines and industry best practices. 2. Establish and adhere to a robust maintenance schedule, including regular inspections and testing.
3	Equipment: Sensors	Faulty sensors are providing inaccurate feedback, impacting the control system's decision-making process.	Upgrade the damper control system and sensors to ensure reliability.
4	Environment: 1. Temperature 2. Humidity	1. Extreme temperatures have caused the expansion and contraction of materials, affecting the damper's structural integrity. 2. The high humidity in the environment has led to corrosion of the damper components.	1. Consider environmental shielding to protect the damper from extreme temperatures. 2. Implement measures to control humidity levels within acceptable limits.

Table 4.6 highlights the critical significance of material selection in determining the longevity of nappy control systems. The material of a damper can deteriorate and compromise its performance over time. Meticulous material selection throughout the design process is crucial, with priority given to corrosion resistance and durability. The prolonged life of nappy control systems can be substantially enhanced by manufacturers who select materials that are well-suited to the operating environment and stress burden of the system.

Moving beyond material, the table delves into the realm of installation and maintenance procedures. Improper installation can lead to misalignment and operational issues. This underscores the importance of adhering to manufacturer guidelines and industry best practices during installation. Additionally, the crucial role of routine maintenance is emphasized, with insufficient maintenance procedures allowing for the deterioration of critical components. By establishing and diligently following a robust maintenance schedule, operators can prevent avoidable damage and ensure the system's continued efficiency.

Furthermore, the potential drawbacks linked to malfunctioning equipment are also emphasized in the table. The third row specifically attributes inaccurate feedback to malfunctioning sensors, which impedes the decision-making process of the control system. To ensure the accuracy and dependability of sensors, this underscores the importance of routine calibration and testing. The system's overall performance and stability can be substantially improved by investing in the replacement or upgrade of obsolete or unreliable sensors.

Finally, the table acknowledges that environmental factors have a substantial effect on the health of newborn control systems. Extreme temperatures can induce material expansion and contraction, compromising the structural integrity of the system. In order to address this potential hazard, it is imperative to use environmental shielding or choose materials that possess suitable thermal expansion coefficients. Additionally, elevated levels of humidity have the potential to induce corrosion in components, thereby requiring the implementation of humidity control measures in order to preserve an optimal operating environment.

4.4 Plan Preventive Maintenance

4.4.1 Preventive Maintenance

It is essential to plan preventive maintenance for components in an AHU, which includes systematic scheduling, inspections, and duties that are particular to the components of the unit. This ensures the effective and secure operation of equipment and systems.

No	Description	Freq	Done	Pass / Fail		Remarks
				(P)	(F)	
1.0	Filter					
a.	Inspect all air filters for any visible damage or clogging	M				Original Plan
b.	Measure the differential pressure across the filters.	M				New Plan
c.	Replace all air filters					
	i. Primary filters for AHU.	6M				Original Plan
	ii. Secondary filters for AHU.	6M				Change yearly to 6 month
d.	Clean filter frames and housings.	3M				New Plan
e.	Check and replace any damaged seals or gaskets.	6M				Original Plan
f.	Inspect the filter housing and frame.	6M				New Plan
g.	Check the AHU and filter system	Y				Original Plan
2.0	Indicator light					
a.	Inspect indicator light for any signs of pyhsical damage, loose connection or burnt-out-bulbs.	M				Original Plan
b.	Check for proper illumination and clarity of indicators.	M				Original Plan
c.	Clean indicator light covers or lenses.	M				Original Plan
d.	Check the electrical connections of the indicator lights.	3M				New Plan
e.	Test each indicators light	3M				New Plan
f.	Test the indicators light under beckup power.	3M				New Plan
g.	Check and recalibrate the indicator light	6M				New Plan
h.	Ensure that indicator light seals or gaskets	6M				Original Plan
i.	Replace indicator light bulbs	Y				Original Plan
3.0	Fire damper					
a.	Check for any visible damage, corrosion, or obstructions.	M				Original Plan
b.	Ensure that fire dampers opens and closes properly.	M				Original Plan
c.	Ensure that there no signs of wear or tear	M				Original Plan
d.	Inspect the linkage and moving parts for cleanliness and proper operation.	3M				New Plan
e.	Clean the dampers blade and surrounding areas the remove any dust.	3M				New Plan
f.	Inspect the intergrity of the seals and gaskets.	3M				Original Plan
g.	Conduct a comprehensive fucntional test.	Y				New Plan
4.0	Motor bearing					
a.	Inspect motor bearings for any visual signs of wear or corrosion.	M				Original Plan
b.	Check for oil and grease leaks around the bearings.	M				Original Plan
c.	Monitor the operating temperature of the bearings.	M				New Plan
d.	Check and tighten bolts.	M				Original Plan
e.	Check for any unusual noise during operation.	3M				New Plan
f.	Evaluates the availability of spare parts and replace.	6M				New Plan
g.	Evaluate the overall condition of motor bearings.	Y				Original Plan

Figure 4. 15 Plan new preventive maintenance

AHU is a crucial component in maintaining thermal comfort and excellent air quality for inhabitants in a well-functioning building. Nevertheless, similar to any fragile apparatus, the AHU necessitates consistent care and maintenance in order to operate optimally. The purpose of this preventive maintenance checklist is to provide specialists with a clear and concise guide detailing the crucial actions required to ensure the optimal functioning of AHU.

The checklist is categorized into four areas, each specifically addressing a crucial element of the AHU: filters, indicator lights, fire dampers, and motor bearings. The document breaks down the tasks that require completion at various intervals, including monthly, semi-annual, and annual basis. By placing key checks at the top of the priority list, this hierarchical approach ensures that no area is overlooked or disregarded. This new plan of preventive maintenance will be compared with the original plan of preventive maintenance. To produce a more extensive maintenance plan schedule and increase the long-term life of components

Some key changes have been made to the AHU maintenance schedule. The maintenance schedule originally included monthly checks for damage and replacement of filters every 6 months. Instead of relying solely on visual inspection, the new plan opts for a monthly measurement of differential pressure across the filters to determine replacement. This data-driven approach potentially saves money by replacing filters only when necessary. In addition, cleaning filter frames and housings every 3 months improves airflow and AHU efficiency. Finally, inspections of the filter housing and frame are now happening every 6 months instead of yearly, proactively detecting potential issues before they can impact the AHUs. These adjustments promise better performance, cost savings, and peace of mind.

The original plan for indicator light maintenance encompassed a set of monthly tasks, including inspections for physical damage, loose connections, and burnt-out bulbs. It also involved checks for proper illumination and clarity, cleaning of covers or lenses, and semi-annual assessments of indicator light seals or gaskets, with bulb replacements as necessary. The revised plan introduces a more comprehensive approach, incorporating tasks such as checking electrical connections, testing each indicator light, assessing their performance under backup power, and recalibrating as needed. The new plan aims to increase the effectiveness of preventing issues with the indicator lights. By adding tasks like electrical connection checks and performance testing, the maintenance routine becomes more thorough and proactive. These additions are likely aimed at improving the reliability and functionality of the indicator lights. Regular checks and recalibration also can help detect any early signs of malfunction or drift in the indicator lights. Addressing these issues promptly can prevent the lights from displaying inaccurate information, avoiding confusion or misinterpretation of system status.

The original plan for fire damper inspection encompassed fundamental procedures such as visual inspection, operational checks, scrutiny for wear and tear, and assessment of seal and gasket integrity. However, a new plan has been introduced to enhance the reliability of fire dampers. Notably, there is an increased frequency in the inspection of linkages and moving parts. This adjustment aims to ensure the continuous smooth operation of the damper, minimizing the risk of malfunction due to the accumulation of dirt or debris. Additionally, a novel requirement involves the regular cleaning of damper blades and their surroundings to prevent the hindrance of operation during a fire. Perhaps most significantly, a comprehensive functional test has been introduced, ensuring that the fire damper effectively closes in response to a fire emergency. These changes collectively signify a proactive approach to identifying and addressing potential issues promptly, thereby bolstering the overall reliability and functionality of fire dampers in critical safety scenarios.

The original plan for motor bearing maintenance outlined routine visual inspections on a monthly basis to identify wear, corrosion, oil leaks, and other potential issues. It also included assessments of the overall condition and the tightening of bolts to prevent vibration and misalignment. A new plan enhances the proactive monitoring of motor bearings. Instead of relying solely on monthly visual inspections, the revised strategy incorporates continuous monitoring of operating temperatures to detect problems before they become visible. Additionally, a more comprehensive approach involves checking for unusual noises during operation every three months, as these can serve as early indicators of bearing failure. Furthermore, a systematic evaluation of spare parts availability and replacement every six months has been planned, ensuring the readiness of necessary components to minimize downtime in the event of a bearing failure.

In summary, the updated preventive maintenance plan for the AHU signifies a proactive shift toward ensuring the reliability and efficiency of essential components. With more frequent cleaning for filters and check indicator lights, the plan aims to sustain optimal air quality and promptly identify any issues. The inclusion of rigorous assessments for fire dampers, encompassing frequent checks on moving parts and a comprehensive functional test, underscores a commitment to enhancing safety measures. Additionally, the motor bearing maintenance plan's evolution to continuous temperature monitoring, periodic noise assessments, and strategic spare part evaluations reflects a comprehensive strategy for early issue detection and swift resolution. Overall, these refinements collectively contribute to a more robust preventive maintenance framework, promoting the longevity, performance, and safety of the AHU.

4.5 Comparison of Total Downtime

Breakdowns in the facilities of a building can lead to costly downtime, decreased productivity, and potential damage to equipment. Addressing breakdowns promptly is essential for maintaining a smooth workflow and ensuring uninterrupted operations. A comparative table can be created to measure the effectiveness of preventive maintenance in reducing breakdowns. This table should include key metrics related to the frequency and duration of breakdowns before and after the implementation of preventive maintenance measures.

Table 4. 7 Comparison of downtime

No.	Component	Downtime before implementing (hours)	Expected Downtime after implement
1	Fire damper	457.18	Decrease
2	Indicator light	381.5	Decrease
3	Motor bearing	14878.55	Decrease
4	Filter	464.15	Decrease

The pre-implementation downtime is significantly less than the post-implementation downtime for all four components. For example, the fire damper's downtime prior to plan implementation was 457.18 hours, and it is expected to decrease after implementation.

Table 4.7 also shows that the expected downtime after implementing the plan is lower than the actual downtime before the plan was implemented for all four components. For example, the expected downtime for the indicator light is decreased, but the actual downtime before the plan was implemented was 381.5 hours. Table 4.7 also shows that motor bearings and filters had a total downtime of 14878.55 hours and 464.15 hours before the implementation of the preventive plan. So, the expected downtime will decrease after the plan is implemented.

These findings indicate that the preventive maintenance plan is successful in minimizing the amount of time that the system is not operational. Nevertheless, it is crucial to acknowledge that the table only presents data for a limited duration. There is a possibility that the approach may not be as productive in mitigating downtime in the long term. In general, the table presents evidence suggesting that implementing a preventative maintenance plan can effectively decrease the amount of time equipment is out of service.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The research had been successfully conducted and accomplished the project's objective. This research is intended to assess the effect of preventive maintenance on the results of building maintenance. Extensive study and analysis have shown that preventive maintenance is essential for minimizing unexpected breakdowns, cutting repair expenses, and prolonging the lifespan of building components. The results emphasize the significance of integrating preventive maintenance measures into comprehensive maintenance protocols to achieve optimal outcomes.

In a nutshell, this research focused on optimizing maintenance planning by incorporating preventive, corrective, and scheduled maintenance activities. The project demonstrated that a well-structured maintenance plan leads to increased efficiency, minimized downtime, and better resource utilization. Additionally, In this study, Pareto analysis and RCA were used to identify and improve weaknesses in the maintenance management system. The results of the study show that organizational weaknesses can be overcome by schedule and action.

Furthermore, through a comprehensive review of existing practices and the implementation of suggested improvements, the project successfully identified areas for enhancement. This included training programs for maintenance personnel, implementing preventive maintenance plans on time, and do not neglect corrective maintenance. So, the total downtime will decrease after the new plan of preventive maintenance is implemented.

In summary, this project was successful in assessing and improving the facilities' maintenance schedule and has also produced a useful framework for methodically planning and carrying out facilities preventive maintenance programs. These activities have the potential to greatly improve the equipment's durability, dependability, and sustainability in the facilities building Complex C Putrajaya and provide an invaluable guide to future maintenance programs in comparable environments.

5.2 Recommendation

In recognizing the significance of the lift system as the second highest contributor to breakdowns in building Complex C at Putrajaya, my purpose in recommending a project focused on the lift is to elevate the reliability, efficiency, and user experience within the building. The objective is to implement strategic measures that address the root causes of breakdowns, thereby minimizing downtime and enhancing the overall performance of the lift system. This project will involve a thorough assessment of the existing lift infrastructure, identifying weaknesses, and proposing targeted solutions to mitigate potential issues. Additionally, the implementation plan will prioritize the integration of cutting-edge technologies, such as predictive maintenance tools and real-time monitoring systems, to proactively identify and address maintenance needs. Collaborating with industry experts, lift manufacturers, and maintenance specialists will be crucial to leverage their knowledge for the successful execution of this project. The end goal is not only to reduce breakdown occurrences but also to create a safer, more reliable, and technologically advanced lift system that aligns with the modern standards of building infrastructure. Through this recommendation, we aim to contribute significantly to the overall improvement and efficiency of vertical transportation in building Complex C.

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APPENDICES

Appendix 1 Gant chart phase 1

GANTT CHART FINAL YEAR PROJECT

PROJECT TITLE: THE IMPACT OF PREVENTIVE MAINTENANCE ON BUILDING MAINTENANCE OUTCOMES: A CASE STUDY OF GOVERNMENT BULIDING IN PARCEL C AT PUTRAJAYA
SUPERVISOR'S NAME: TS. AHMAD NIZAM BIN JAMALUDIN
STUDENT'S NAME: MUHAMMAD HAZIM AIMAN BIN HAZMAN

NO	TASK TITLE	DURATION	ACADEMIC WEEK (2023-2024)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
CHAPTER 1: INTRODUCTION																
1.1	Background of Research	14 Days														
		56 Days														
1.2	Problem Statement	14 Days														
		56 Days														
1.3	Research Objectives	14 Days														
		56 Days														
1.4	Job Scope	14 Days														
		56 Days														
1.5	Significance of Study	14 Days														
		56 Days														
CHAPTER 2: INITIAL STUDY																
2.1	Literatre Review	56 Days														
		49 Days														
CHAPTER 3: RESEARCH METHODOLOGY																
Phase 1: Site Visit																
3.1.1	Identify the facilities in buildings	21 Days														
		35 Days														
3.1.2	Draft the questionnaire	14 Days														
		35 Days														
3.1.3	Collect the data	21 Days														
		35 Days														
3.1.4	Analysis data															
CHAPTER 4: PRE-RESULTS																
4.1	Preliminary Results	14 Days														
		14 Days														
OTHERS																
1	First of Submission Dissertation	1 Days														
		1 Days														
1.1	Logbook	1 Days														
		1 Days														
1.2	Presentation	1 Days														
		1 Days														
1.3	Final Submission of Dissertation	1 Days														
		1 Days														

Appendix 2 Gant chart phase 2

GANTT CHART FINAL YEAR PROJECT

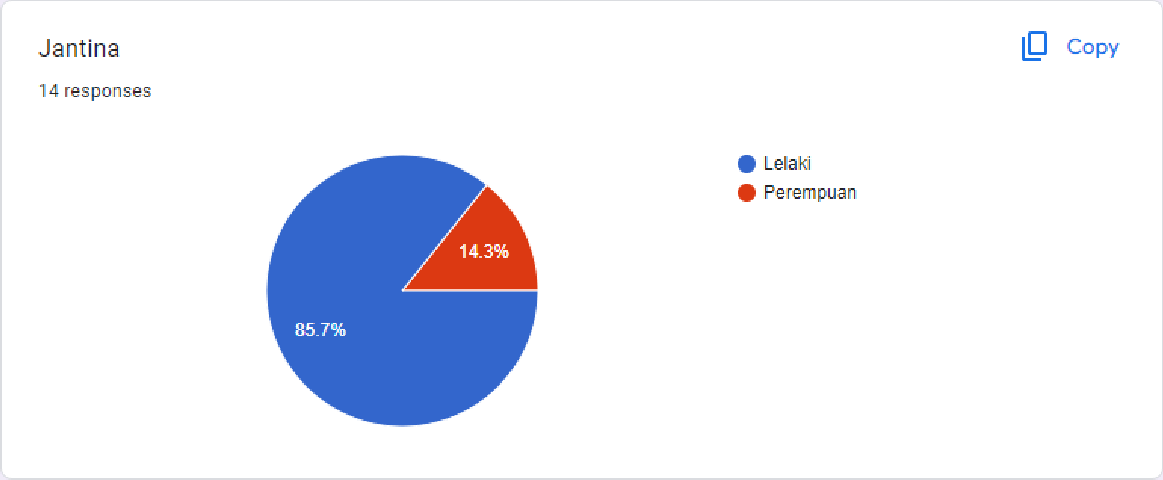
PROJECT TITLE: THE IMPACT OF PREVENTIVE MAINTENANCE ON BUILDING MAINTENANCE OUTCOMES: A CASE STUDY OF GOVERNMENT BULIDING IN PARCEL C AT PUTRAJAYA

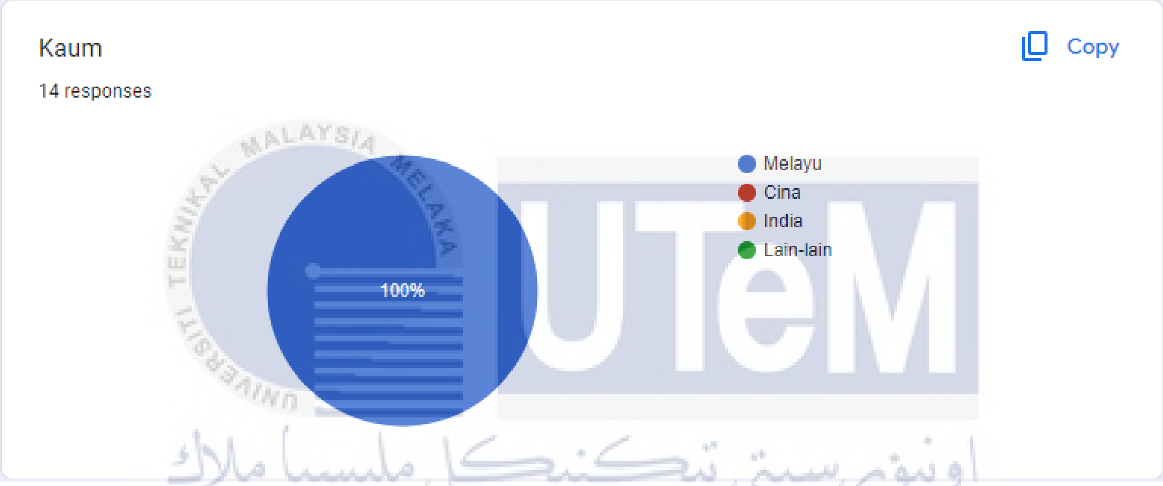
SUPERVISOR'S NAME: TS. AHMAD NIZAM BIN JAMALUDIN

STUDENT'S NAME: MUHAMMAD HAZIM AIMAN BIN HAZMAN

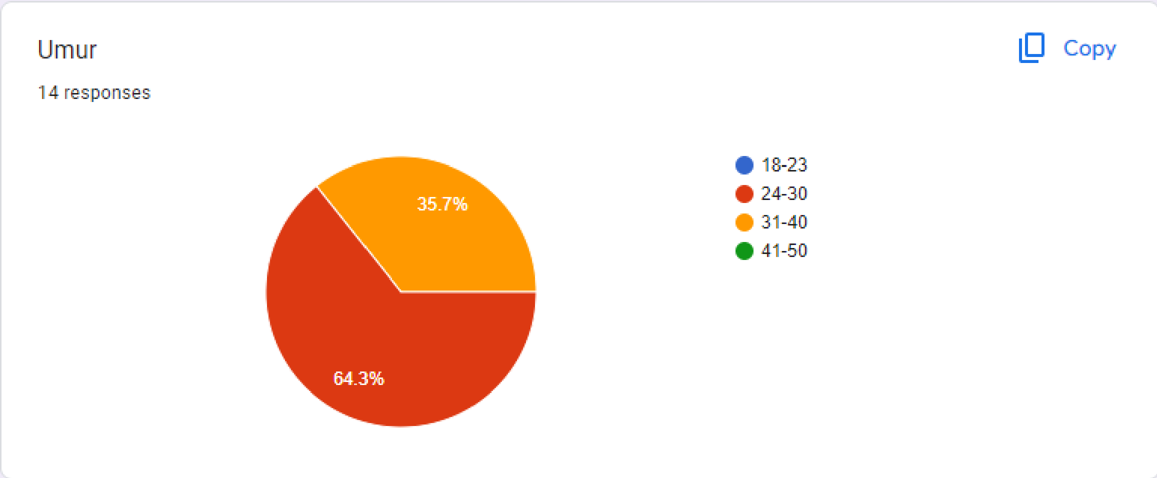
NO	TASK TITLE	DURATION	ACADEMIC WEEK (2023-2024)													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Project Milestones																
Phase 2: Collect the data																
3.2.1	Site visit	1 Days														
		1 Days														
3.2.2	Distribute the questionnaire to the	21 Days														
		35 Days														
3.2.3	Identify the facilities in building	21 Days														
		35 Days														
Phase 3: Analysis data																
3.3.1	Analyse questionnaire	35 Days														
		49 Days														
3.3.2	Identify the facilities break down	35 Days														
		49 Days														
3.3.3	Identify sub-component of facilities break d	35 Days														
		49 Days														
3.3.4	Analyse component break down using RCA	35 Days														
		49 Days														
CHAPTER 4: RESULTS																
4.1	Results	21 Days														
		35 Days														
4.2	Discussion	21 Days														
		35 Days														
CHAPTER 5: CONCLUSION																
4.1	Conclusion	14 Days														
		21 Days														
4.2	Recommendation	14 Days														
		21 Days														
OTHERS																
1	First of Submission Dissertation	1 Days														
		1 Days														
1.1	Logbook	1 Days														
		1 Days														
1.2	Presentation	1 Days														
		1 Days														
1.3	Final Submission of Dissertation	1 Days														
		1 Days														

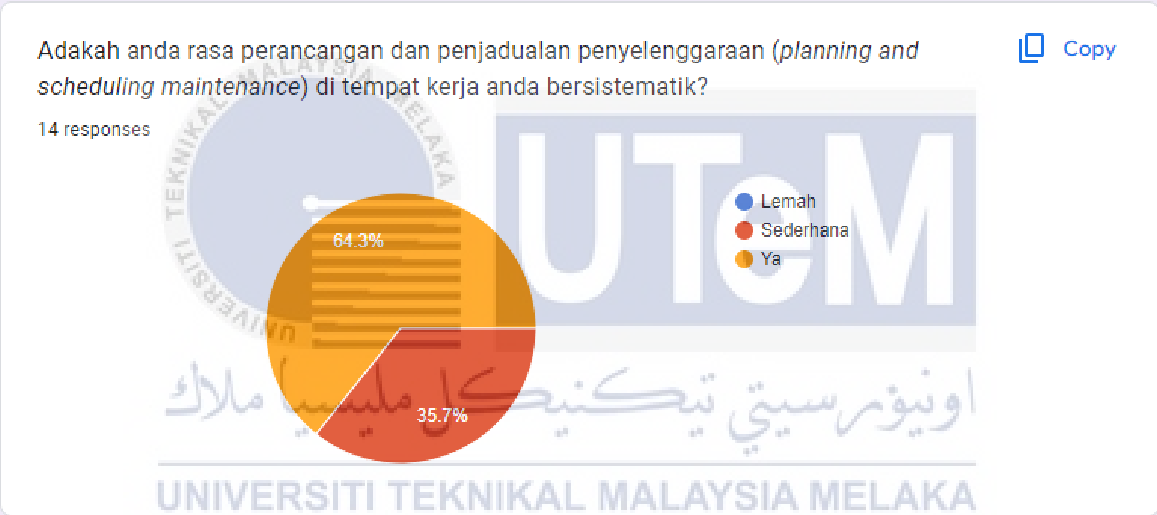
Appendix 3 Questionnaire





Appendix 4 Questionnaire

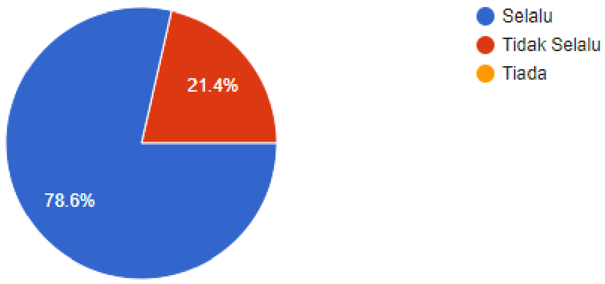




Appendix 5 Questionnaire

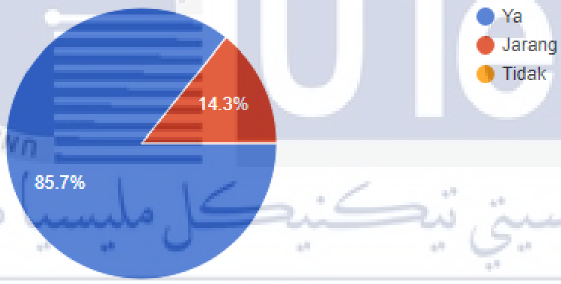
Berapakah pemeriksaan perancangan dilakukan bagi kerja penyelenggaraan dilakukan sebelum berlakunya kerosakan pada sesuatu peralatan/mesin. Copy

14 responses



Adakah tugas penyelenggaraan pencegahan (*preventive maintenance task*) selalu dibuat di tempat kerja anda? Copy

14 responses

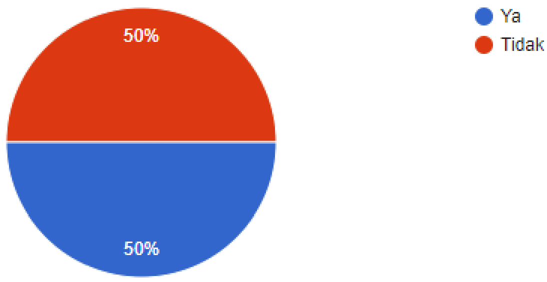


Appendix 6 Questionnaire

Adakah *maintenance downtime* di tempat kerja anda tinggi?

Copy

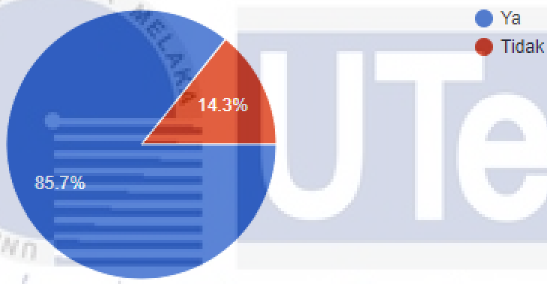
14 responses



Adakah bilangan (*work order*) di tempat kerja anda tinggi?

Copy

14 responses

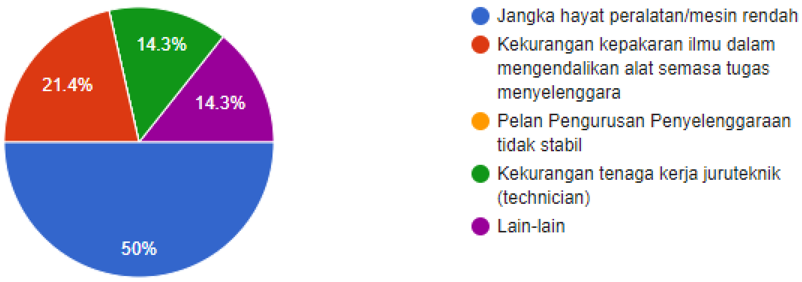


Appendix 7 Questionnaire

Apakah faktor yang menyebabkan berlakunya pencegahan pembetulan (*corrective maintenance*) di tempat kerja anda tinggi?

Copy

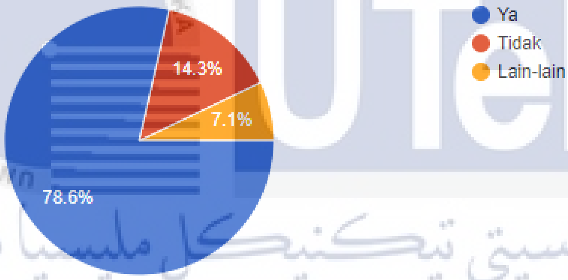
14 responses



Adakah anda ingin membuat perubahan terhadap sistem pengurusan penyelenggaraan di tempat kerja anda supaya menjadi lebih bagus?

Copy

14 responses



Appendix 8 Questionnaire 1-person

Is downtime maintenance at your workplace high? *

yes.specially AHU

What is the main problem that occurs at your place? *

The main problem is AHU

From your point of view, what are the causes that cause damage to always occur? *

lifetime.exceed 20 years

Would a new preventive and corrective plan be required at your workplace? *

yes.ppm can extend the lifetime of AHU

How many times training and skills made within 3 months for employees? *

once per months

Appendix 9 Questionnaire 2-person

Is downtime maintenance at your workplace high? *

Yes

What is the main problem that occurs at your place? *

Airconditioning temperature

From your point of view, what are the causes that cause damage to always occur? *

The setup of the temprature

Would a new preventive and corrective plan be required at your workplace? *

Yes

How many times training and skills made within 3 months for employees? *

Twice

Appendix 10 Questionnaire 3-person

Is downtime maintenance at your workplace high? *

Yes, the downtime maintenance at my workplace is high due to AHU

What is the main problem that occurs at your place? *

The main problem is AHU which is Air Handling Unit that occurs at my place

From your point of view, what are the causes that cause damage to always occur? *

The causes that cause damage to the AHU are lack of technician skill and not following the schedule of preventive maintenance

Would a new preventive and corrective plan be required at your workplace? *

Yes, we need the new plan preventive and corrective maintenance to reduce the downtime maintenance

How many times training and skills made within 3 months for employees? *

once per month

Appendix 11 Questionnaire 4-person

Is downtime maintenance at your workplace high? *

Yes

What is the main problem that occurs at your place? *

AHU and lift

From your point of view, what are the causes that cause damage to always occur? *

not follow the plan preventive maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

twice

Appendix 12 Questionnaire 5-person

Is downtime maintenance at your workplace high? *

Yes

What is the main problem that occurs at your place? *

Airconditioning

From your point of view, what are the causes that cause damage to always occur? *

miss deadline corrective maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

once

Appendix 13 Questionnaire 6-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

lift

From your point of view, what are the causes that cause damage to always occur? *

lack of skill maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

twice

Appendix 14 Questionnaire 7-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

AHU

From your point of view, what are the causes that cause damage to always occur? *

1) lack of skill maintenance
2) miss deadlince of corrective maintenance
3) ignore plan preventive maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

once

Appendix 15 Questionnaire 8-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

AHU

From your point of view, what are the causes that cause damage to always occur? *

Ignore deadline corrective maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

once

Appendix 16 Questionnaire 9-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

AHU

From your point of view, what are the causes that cause damage to always occur? *

lack of skill trainning and lifetime exceed

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

once

Appendix 17 Questionnaire 10-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

Lift

From your point of view, what are the causes that cause damage to always occur? *

Ignore corrective deadline

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

twice

Appendix 18 Questionnaire 11-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

AHU

From your point of view, what are the causes that cause damage to always occur? *

Lack of skill trainning and not follow plan preventive maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

twice

Appendix 19 Questionnaire 12-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

AHU

From your point of view, what are the causes that cause damage to always occur? *

lack of technician skill

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

once

Appendix 20 Questionnaire 13-person

Is downtime maintenance at your workplace high? *

Yes

What is the main problem that occurs at your place? *

AHU

From your point of view, what are the causes that cause damage to always occur? *

lack of preventive maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

twice

Appendix 21 Questionnaire 14-person

Is downtime maintenance at your workplace high? *

yes

What is the main problem that occurs at your place? *

AHU

From your point of view, what are the causes that cause damage to always occur? *

ignore deadline corrective maintenance

Would a new preventive and corrective plan be required at your workplace? *

yes

How many times training and skills made within 3 months for employees? *

once